TM5-665

WAR DEPARTMENT TECHNICAL MANUAL

OPERATION OF

SEWERAGE AND SEWAGE TREATMENT FACILITIES

AT FIXED ARMY INSTALLATIONS

WAR DEPARTMENT • NOVEMBER 1945

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BY ORDER OF THE SECRETARY OF WAR:

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Chief of Staff

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The courtesy of the Federation of Sewage Works Associations and the technical press in permitting broad use of material contained in their publications, and of the manufacturers of sewage works equipment in providing illustrative material is hereby acknowledged.

CONTENTS

CHAPTER 1

ARMY SEWAGE TREATMENT AND DISPOSAL

Section I. INTRODUCTION

1. Purpose and Scope

This Technical Manual is an operating and training guide for personnel who operate and maintain sewage collection, pumping, treatment, and disposal facilities at fixed Army installations. The material has been compiled from standard texts, engineering and professional journals, manufacturers' instructions, and the operating reports of various municipal and Army utilities. Many of these sources are listed in appendix IV.

a. CONTENTS. The text includes the following:

(1) A general discussion of the objectives and need of sewage collection and treatment.

(2) Descriptions of the processes, structures, and equipment used.

(3) Procedures and necessary instructions for proper operation of the various processes and facilities.

(4) Methods of laboratory testing and plant control.

(5) Systems of records to provide plant control and indicate efficiency of treatment units.

(6) Instructions for work organization.

(7) Appendixes containing a glossary of terms, list of abbreviations, tables, and reference texts.

b. MAINTENANCE. Instructions for the preventive maintenance of the structures and mechanical equipment including regular cleaning, inspecting, servicing, adjusting, lubricating and records of maintenance activities are contained in TM 5–666.

Section II. CHARACTERISTICS OF ARMY SANITARY SEWAGE

2. Composition

Sewage is the waste material flowing through the sanitary sewer system. Although it consists principally of water-borne latrine, shower, and kitchen wastes, sewage may contain liquid wastes from the laundry, garbage can washers, airplane and vehicle wash racks, and floor drainage. Sewage quality may vary from hour to hour and day to day; it is usually gray because of the soap it contains although it may be colored by laundry-dye waste, oily from improperly maintained wash-rack traps, or almost clear and colorless during low-flow periods. It contains considerable floating matter, including fecal solids, paper, matches, grease, kitchen refuse, and other debris. Organic and mineral matter constitute only about 0.1 percent by weight of the total volume; about 99.9 percent by weight is water.

a. BIOCHEMICAL OXYGEN DEMAND. Most of the mineral matter consists of salts contained in the domestic water supply. The organic matter, primarily of human or food origin, is unstable and readily decomposed and oxidized by biological or chemical agents to form more stable substances. The quantity of dissolved oxygen required to stabilize sewage solids is called biochemical oxygen demand (BOD), the most common means of expressing sewage strength.

b. SUSPENSIONS. Mineral and organic matter exist both in suspension and in solution. From 50 to 80 percent of these solids are organic and volatile (may be vaporized by drying and burning). The suspended material filtered from a known quantity of sewage determines a value called suspended solids, also commonly used to measure sewage strength. Most suspended material settles if the sewage remains still for a time.

c. BACTERIA. Sewage contains vast quantities of bacteria which originate in discharged wastes. The feeding activities of these organisms assist in decomposing sewage. While most of them are harmless to men, pathogenic organisms discharged by victims or carriers of infectious diseases such as typhoid, the dysenteries, and other intestinal infections may be present.

d. DECOMPOSITION. Decomposition of sewage solids constantly changes the characteristics of raw sewage; biological decomposition is anaerobic or aerobic. Anaerobic decomposition, putrefaction, is caused by organisms active largely in the absence of oxygen; its products are unstable and usually odorous. Aerobic decomposition occurs through the activity of organisms living in the presence of free oxygen; its products are stable and without unpleasant odor. Raw sewage may contain solids in various stages of decomposition ranging from undecomposed material to the stable products of aerobic reactions.

e. ADULT WASTE. The average amount of adult waste remains rather constant. For design purposes, a per capita BOD value of 0.20 pounds per day is assumed for Army establishments.

3. Quantity

a. FACTORS. Quantity of sewage depends on per capita use of water and leakage of ground or rain water (infiltration) into sewers. This quantity is augmented by laundry wastes and wastes from automobile and airplane washing. Sewage flow may be estimated as 70 percent of the domestic water consumption unless considerable water is used for irrigation or lawn sprinkling.

b. FLUCTUATION. Sewage flow is usually comparable at Army installations of similar size and nature. The regulated activity of a military installation causes high maximum and low minimum rates of flow. The maximum rate, which varies from two to three times the average flow, may occur at several definite periods during the day. The night flow is low and consists almost entirely of infiltered water and waste from facilities operating night shifts.

Section III. TREATMENT AND DISPOSAL REQUIREMENTS

4. Objectives

The sewage collection system removes offensive and potentially dangerous waste from dwelling and training areas and brings it to a treatment plant or point of disposal. The primary purpose of the treatment plant is to change the sewage or any products of treatment so the receiving waters or land is not damaged. The plant must be operated with efficiency, economy in cost and manpower, and in a manner consistent with the requirements of the receiving body of water. Damage by inadequate treatment of sewage may include the following:

a. Contamination of public or private water supplies.

b. Damage to property and depreciation of values.

c. Conditions offensive to sight and smell.

d. Damage to fish and other valuable aquatic life.

e. Contamination of bathing places and shellfish propagation areas.

f. Damage to livestock.

g. Other impairment of water or land for recreation, commerce, or industry.

5. Measuring Requirements and Results of Treatment

a. SURVEYS. Because the primary function of the sewage treatment plant is stream protection, measurement of the plant effluent's effect on the stream water is an important control activity. Initial stream surveys determine the degree of sewage treatment necessary; periodic surveys by plant personnel determine the protection afforded and control plant operation.

These surveys consist of periodic checks above and below the sewage discharge point of stream flows, oxygen and solids characteristics, bacterial content, and general appearance. Methods for making these surveys are given in paragraph 149.

b. NATURAL PURIFICATION. Streams are capable of self-purification, using natural settling and anaerobic and aerobic decomposition. Therefore, disposal of sewage in a stream is one available treatment process, although excessive overloads interfere just as they do with plant operation. Most sewage plant processes are about the same as natural processes, except that they are confined, intensified, and controlled. The same tests used in the stream survey are used in plant control because they have the same important bearing on proper sewage disposal.

c. VARYING REQUIREMENTS. Each disposal point has its own requirements to be determined and met by making the necessary tests required by local conditions. For instance, shellfish propagation areas receiving effluents are tested for bacterial contamination. Effluents confined to areas within the limits of the military reservation must be carefully watched to see that no damage results. Seasonal changes in requirements must be considered. Hot, dry weather speeds up biological activity, causes rapid depletion of oxygen, and usually means low stream flows, making more effective treatment necessary than during periods of high water and low temperatures.

Section IV. COLLECTION, TREATMENT, AND DISPOSAL ELEMENTS

6. Sewerage System

A sewerage system consists of all facilities for the collect'on, transportation, pumping, treatment, and disposal of domestic sewage from the Army post. (See fig. 1.)

7. Collection Systems

Sanitary collecting systems at Army posts are designed to remove domestic sewage only. All surface drainage is excluded to avoid constructing large sewers and treating large volumes of sewage during storms. The collecting systems include the following:

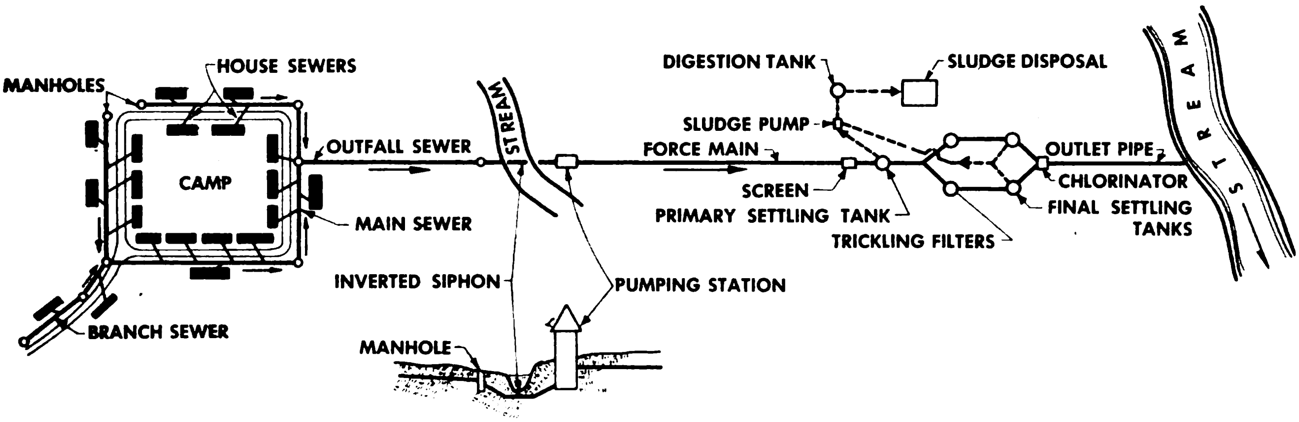


FIGURE 1. *Complete sewerage system.*

a. HOUSE SEWER. Pipe connecting the sanitary plumbing facilities of a single building to a common sewer.

b. LATERAL SEWER. Line connecting to a branch or other sewer and having no other common sewer tributary to it.

c. BRANCH SEWER. Sewer serving a relatively small area.

d. MAIN SEWER. Sewer to which two or more branches are connected.

e. TRUNK SEWER. Sewer with many branches which provides outlet for a large area.

f. FORCE MAIN. Pipe carrying sewage under pressure from a pumping station.

g. INTERCEPTOR SEWER. Main line intercepting a number of main sewers and connecting to a treatment plant or disposal point.

h. OUTFALL SEWER. Line leading from a treatment plant or collecting system to the final disposal point.

i. INVERTED SIPHON. Sewer depressed below the hydraulic grade line and flowing full at all times.

j. PUMPING STATION. Equipment for lifting sewage to a higher elevation.

8. Devices for Measuring Flow

Treatment plants have flow-measuring devices to determine total flow and rate of flow. They are located either near the inlet or outfall sewer of the plant.

9. Primary Treatment Processes and Facilities

Primary treatment is removal, treatment, and disposal of settleable and floating solids. The following processes and equipment are considered as primary treatment. Individual plants may have some, but not necessarily all, of these facilities.

a. SCREENING OR GRINDING. Screening or grinding consists of removal or other treatment of large solids by the following methods:

(1) *Bar screens.* Series of evenly-spaced bars set in the sewage flow.

(2) *Fine screens.* Perforated plates or fine-mesh wire set on a frame or rotating drum.

(3) *Comminutors.* Machines for cutting or shredding the solids and passing them to the sewage flow.

(4) *Grinders.* Equipment that grinds the solids removed by the screens and returns them to sewage flow.

b. GREASE REMOVAL. Preliminary removal of grease from sewage to avoid clogging filters, pumping equipment, etc., is done in preaeration tanks which aerate the sewage and skim off the floating material.

c. GRIT REMOVAL. Preliminary removal of grit and heavy solids by reduction of velocity protects pumps and equipment.

(1) *Manually-operated grit chambers.* Channels in which flow is retarded and from which settled grit is removed by hand labor.

(2) *Mechanically-operated grit chambers.* Channels from which grit is removed mechanically.

d. SEDIMENTATION AND SLUDGE DIGESTION. The sedimentation and digestion process removes settleable solids by gravity settling and treats sludge by anaerobic digestion.

(1) *Septic tank.* One-story tank for both settling and digestion. Figure 2 shows a typical flow diagram of this method including a drainage field for effluent disposal.

(2) *Imhoff tank.* Two-story tank for both settling and digestion. (See fig. 3.)

(3) *Separate sedimentation tanks.* Tanks with hopper bottoms or mechanical scrappers in which

solids are settled and removed to separate digestion units. (See fig. 4.)

(4) *Separate digestion tanks.* Structures to receive and digest solids removed from the separate sedimentation tanks.

(5) *Gas-utilization equipment.* Gas domes, piping, and burning facilities used to heat digester and buildings.

(6) *Sludge-transfer equipment.* Pumps and appurtenances.

e. Sludge drying and disposal. Sludge drying and disposal include drying and use of digested sludge.

(1) *Sludge drying beds.* Sand beds on which sludge from digestion units is spread for drying.

(2) *Grinders.* Grinding equipment for dried sludge.

(3) *Truck tanks.* Tanks mounted on trucks and equipped to spread wet sludge.

(4) *Lagoons.* Areas for ponding digested sludge.

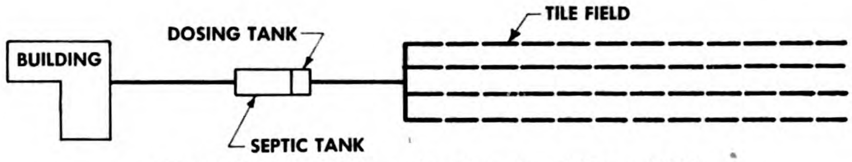
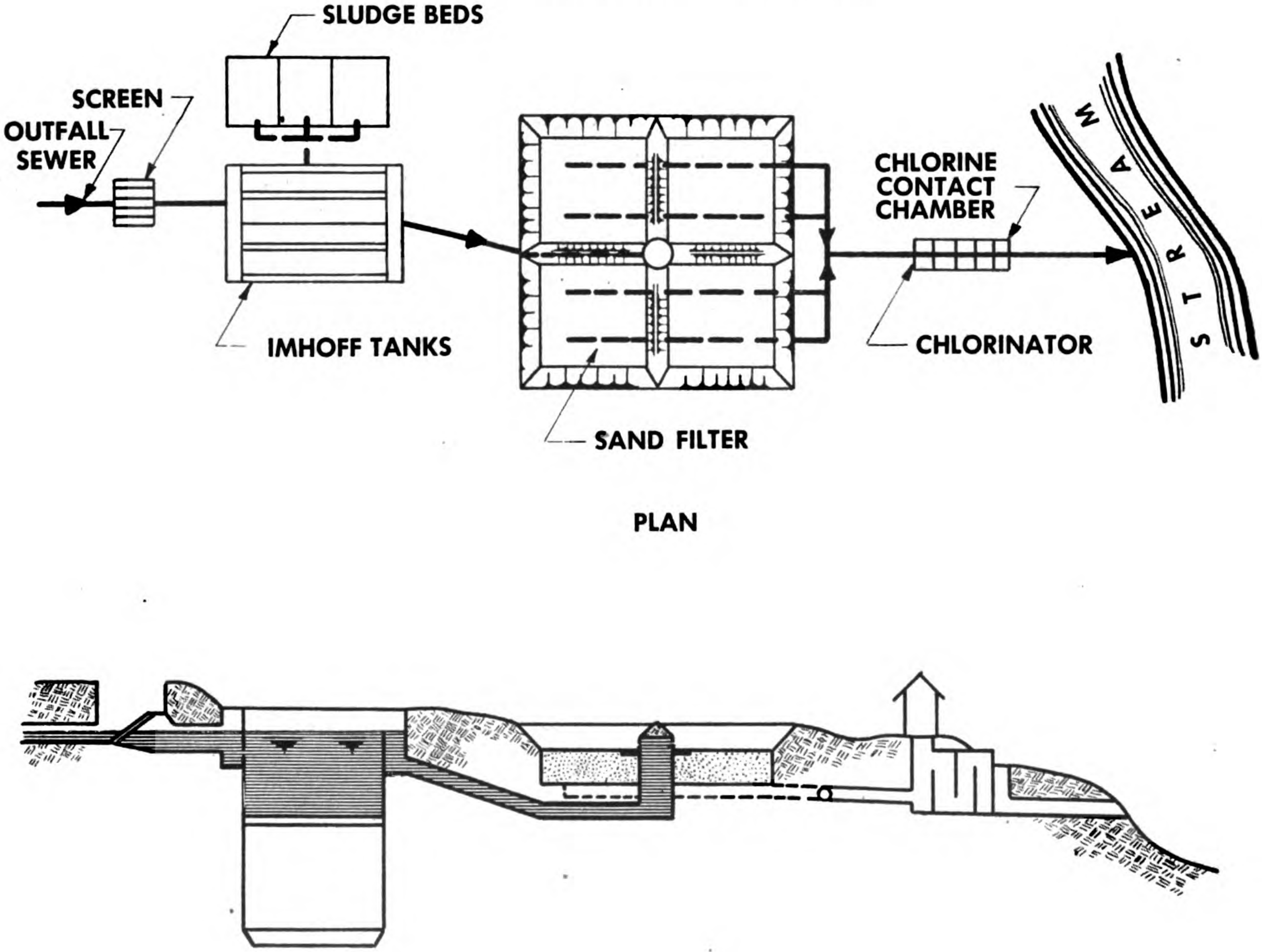


Figure 2. *Flow diagram of septic tank and disposal field.*



PROFILE

Figure 3. *Imhoff-tank and sand-filter plant.*

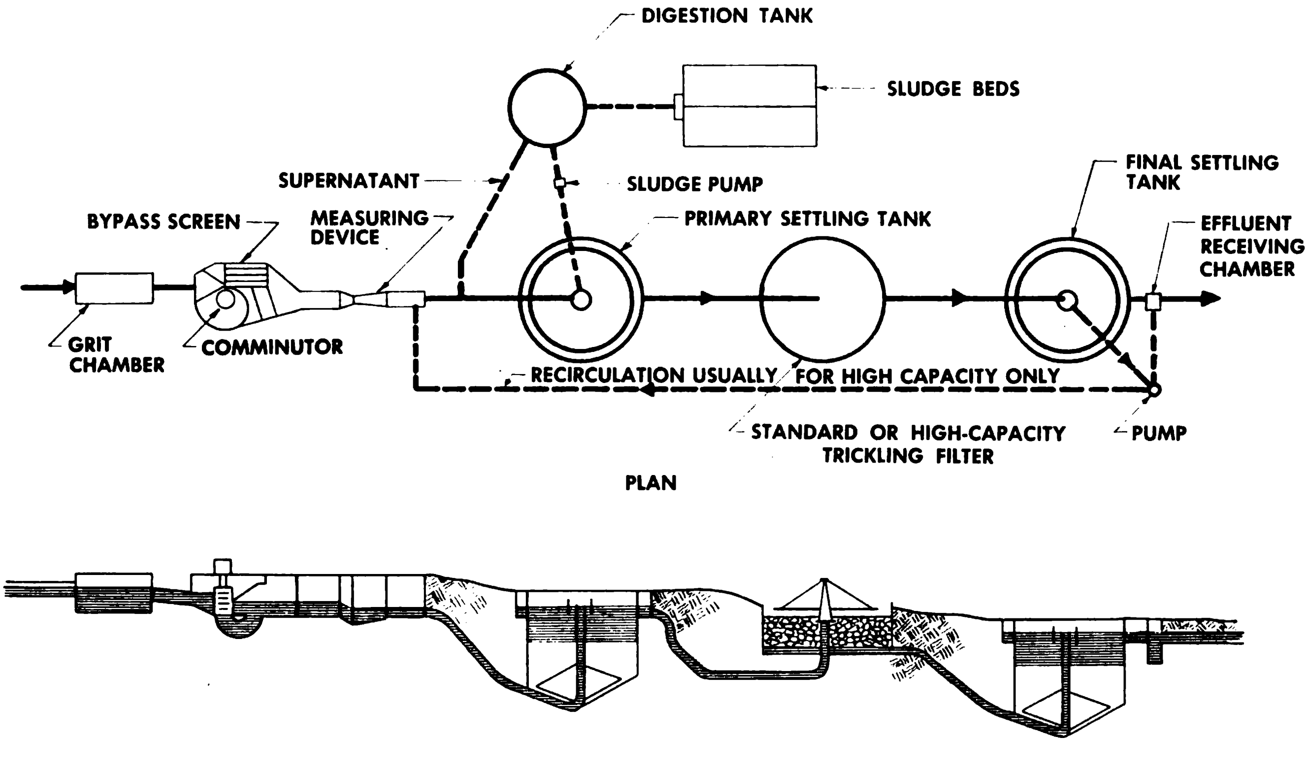


FIGURE 4. *Plain settling with standard and high-capacity filter.*

10. Secondary Treatment Processes and Facilities

Processes and equipment for biological and chemical oxidation of soluble or finely divided sewage solids are secondary treatment.

a. FILTRATION. Filtration is biological oxidation of sewage solids on beds of stone or sand.

(1) *Trickling filters.* Beds of stone where settled sewage is intermittently or continuously distributed. Films of organisms stabilize the solids by aerobic methods. Figure 4 illustrates standard and high-capacity filtration.

(2) *Sand and Dunbar filters.* Beds of underdrained sand on which settled sewage is applied. Oxidation takes place in the bed. Figure 3 is a flow diagram of Imhoff tank and sand filters.

(3) *Dosing tanks.* Tanks and siphons for intermittent application of settled sewage to trickling, or sand filters.

b. CONTACT AERATION. Contact aeration is oxidation in the presence of organisms retained on contact plates; oxygen is provided by the diffusion of compressed air through the settled sewage.

c. ACTIVATED SLUDGE. The activated-sludge method is the process whereby oxidation occurs in aerated sludge containing aerobic organisms. Much of this sludge is removed and returned to the sewage entering the tanks.

(1) *Diffused-air aerators.* Tanks for supplying compressed air through diffuser plates or tubes. Motion of liquid is obtained either by air or mechanical equipment.

(2) *Mechanical aerators.* Tanks equipped mechanically to produce motion and aeration of contents.

d. SECONDARY SETTLING. Removal of suspended material in the effluents from secondary oxidation processes is accomplished by equipment similar to that used in primary separate sedimentation.

e. SUBSURFACE IRRIGATION. Subsurface irrigation is application and disposal of septic tank effluents to the soil. (See fig. 2.)

(1) *Subsurface tile fields.* Tile lines in loose and porous soil into which the effluent is continuously or intermittently dosed.

(2) *Leaching cesspools.* Lined walls dug in gravel or loose soil into which septic-tank effluents are discharged for percolation.

11. Chlorination

Chlorine or hypochlorite is used for disinfection of plant effluents, odor control, or other control purposes.

a. Chlorinators. Mechanical devices for automatically or manually applying definite doses of chlorine gas.

b. Hypochlorinators. Devices for applying hypochlorite.

c. Contact tanks. Tanks which hold sewage long enough to allow contact with chlorine.

12. Final Aeration

Final aeration is the application of oxygen to the final effluent by step aerators or other devices. Figure 5 shows the final effluent from a sewage treatment plant passing down a step aerator.

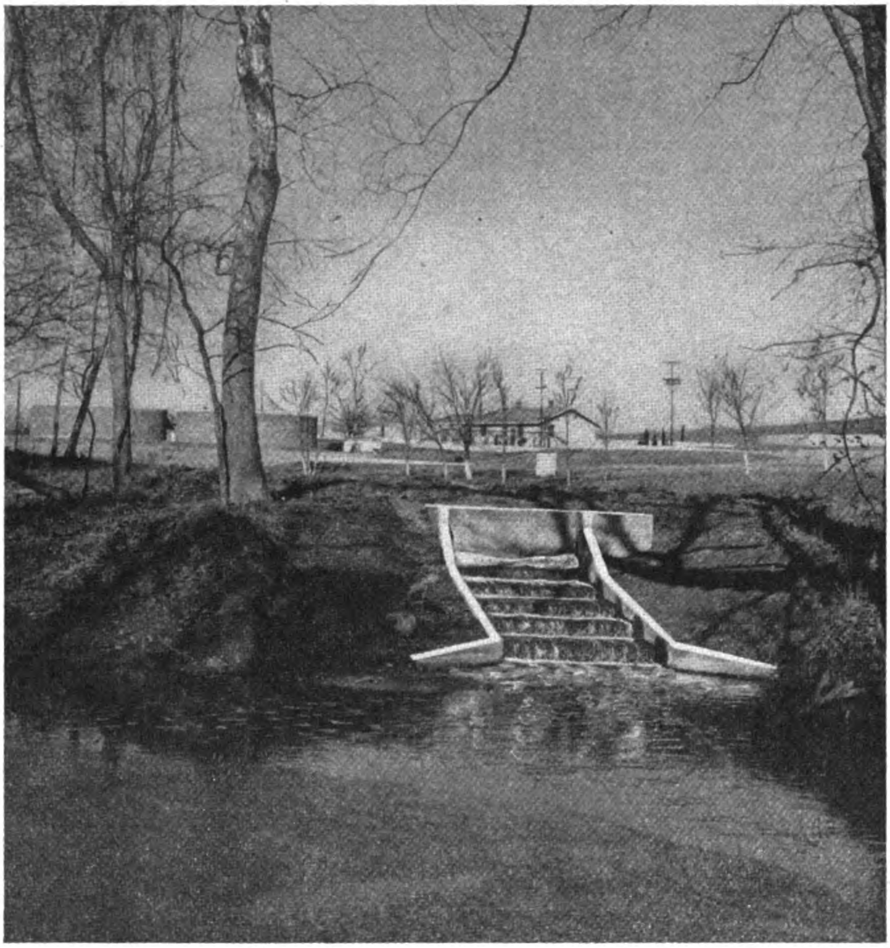


Figure 5. *Step aerator and disposal to stream.*

13. Disposal

a. Streams or other bodies of water. Disposal of raw or treated sewage may be done by dilution in bodies of water through surface or submerged outlets. (See fig. 5.)

b. Land. Disposal on land may be done as follows:

(1) Normally dry stream beds.
(2) Broad irrigation and irrigation ditches.
(3) Percolation beds and natural sand filters.
(4) Leaching cesspools and subsurface irrigation.

c. Evaporation. Disposal by evaporation is usually combined with percolation or oxidation in ponds.

Section V. ORGANIZATION OF OPERATION AND MAINTENANCE

14. Direction of Work

A well-defined organization for the direction of work is essential to efficient, economical operation of a sewage disposal system.

a. Responsibility. Responsibility for sewage treatment and disposal must be definitely fixed. A functional chart showing the responsibilities assigned to each individual and covering all responsibilities is recommended. The sanitary engineer, superintendents, and foremen are given the fullest possible authority over personnel under their direction. Supervising personnel must check night-shift operation as well as daytime work.

b. Organization. Operation and maintenance of the sewage collecting system, pumping facilities, and treatment plant are made the responsibility of one man to insure full coordination of operations. This responsibility is best combined with that for water supply under a sanitary engineer or supervisor. The division of work depends on size of post and type of treatment plant and sewerage system.

(1) *Sewer systems.* Full time personnel are permanently assigned to sewer system maintenance as required by a properly scheduled work load. Such personnel may be combined with those responsible for operation and maintenance of the water distribution system or the water, gas, and underground steam system. Additional personnel are obtained as required from the plumbing shop and labor pool. At small posts, practically all maintenance and repair of the sewer system may be done by the plumbing shop or other personnel on work orders. Responsibility for maintenance is *not* delegated when actual work is done by others.

(2) *Remote pumping stations.* Remote sewage pumping stations are attended from one to three times per day either by sewage plant personnel or by water pumping personnel, depending upon the number of automatic water and sewage pumping stations and their location relative to fully attended water and sewage plants.

(3) *Treatment plants.* Sewage treatment plants normally require attendance 12 to 24 hours a day, 7 days per week; in fairness to employees, a rotation of shifts, preferably on a duty roster, is desirable. The number of shifts is held to the minimum necessary to control processes and output with consideration given to spreading the work load as evenly as possible between shifts.

15. Personnel and Training

Effective utilization of manpower is important during a national emergency; it is important at all times for efficiency and economy. Because sewer systems and treatment plants vary in design, arrangement, and compexity, modification of established yardsticks for determining the number of personnel is frequently necessary. Each installation must be studied to determine the minimum number of shifts and personnel needed to insure adequate control and maintain efficient treatment.

a. Requirements. In making personnel studies, variable factors to be considered include the following:

(1) Number of pumping stations and relative location to treatment plant.

(2) Type of stations and method of screenings removal (hand raked, racks, mechanical rakes, or shredders).

(3) Type of pump control (manual or automatic).

(4) Type and complexity of treatment.

(5) Type of chlorinator.

(6) Provision for emergency night attendance.

b. Economy in personnel. Consideration is given to saving manpower by installing automatic equipment such as time-clock controls, flow recorders, and screenings shredders to replace manual equipment requiring constant attendance. In some cases, overlapping shifts provide the additional personnel needed for morning and evening peak flows. As shown by factors discussed above, two posts with the same population may differ widely in their personnel requirements for operating and maintaining the sewer system and treatment plant.

(1) *Selection of personnel.* Treatment plant and sewer system operating and maintenance personnel should have the best training possible. Sanitary engineers through wide professional contacts can assist in locating qualified men for key positions. Those having previous experience with municipal systems or similar fields should be employed if possible. Personnel with latent abilities can be promoted through job-training programs or by transfer between posts to get maximum use of ability. Since much mechanical equipment is involved, mechanical aptitude is a valuable asset. Supervisory and operating personnel should be able to make independent and safe decisions in unusual situations. Operating personnel must realize the importance of their work and be shown that the health and safety of the command depend upon the conscientious performance of their duties.

(2) *Training methods.* Continual training is required to maintain high standards, insure efficient operation, and keep personnel informed of current technical developments. Short courses or conferences for key personnel are held annually by the

service command. Additional training is provided by service command personnel during routine visits to the post. Local training of all personnel is done by the works supervisor. Assistance can often be given by the post sanitary officer. Study of this manual and TM 5-666 is required. Self-improvement by studying these manuals, reading technical texts and journals, attending short courses of the State health departments, or meetings of local Sewage Works Associations, and visits to similar plants at nearby posts or municipalities must be encouraged. Contribution of suggestions for improving operation and construction of simple gadgets and labor-saving devices should be urged. Many suggestions warrant articles for publication in technical periodicals.

16. Materials, Stocks, and Requirements

In selecting materials and stock to be kept on hand, the first consideration is practical, economical continuous service. Stock-level control (TM 5–601 (when published)) was instigated to assist, not hinder, those concerned. Proper stock control prevents exhaustion of necessary stock and hoarding of unnecessary items.

a. Expendable stock. Experience based on maintenance and operating reports is used to establish stock levels for such items used at a fairly uniform rate as pump packing, treating chemicals, and laboratory reagents.

b. Standby or insurance items. Materials seldom used but needed to safeguard health, insure uninterrupted operation of facilities, or prevent destruction of property are called standby or insurance items. They are not subject to normal stock-level procedures. Although several sewerage system items fall into this category, nonessential items or items to which regular stock-control procedures can be applied must not be included. Seldom-used emergency-repair parts for a chlorinator, such as a spare bell jar, auxiliary chlorine valves, and cylinder connections are classified as standby and insurance items, but if several chlorinators are in use, stocking, interchangeable parts for each chlorinator is not justified. Many sewer repairs are of an emergency nature to prevent nuisance and health hazards, but much repair work at pumping stations and treatment plants can be anticipated with repair items being secured as needed. In stocking for emergency repairs, availability of repair parts at other posts, neighboring municipalties, or supply houses should be considered. A minimum of unusual, hard-to-get items, such as large, uncommon sewer pipe and fittings, are carried in stock. Most other items which may be needed quickly are small, relatively inexpensive, easily stored, and should be stocked even though none have been required for a long time. Sound judgment based on a study of the sewer system and plant is needed to determine the type and number of emergency items to stock. Reorder is made as soon as material is drawn from standby stock.

c. Supply of material. Supervisory sewage treatment personnel should know the normal delivery time and all supply sources for materials required in operation and maintenance. The need for continuous service requires that stock levels be watched and materials ordered far enough in advance. Follow-up on delivery schedules and assistance to the procuring officer in locating alternate sources of supply are essential when delivery is delayed. Sources of supply and examples of material obtained from each are listed below.

(1) Surplus and excess stock lists: pipe, chemicals, pumps, and construction and maintenance tools.

(2) Depots: calcium hypochlorite, grade A.

(3) Service command engineer warehouses: chlorine cylinders and chemical feeders.

(4) Other services: gas masks and canisters and lubricants.

(5) Treasury procurement schedules: certain chemicals.

(6) Local purchase: replacement parts for all commercial equipment, pipe, chemicals, and laboratory equipment and supplies.

17. Cost Accounting

Cost accounting reflects current cost of repairs and utilities work; it is a yardstick to measure trends at a given post; it can be a basis for comparing posts if all factors are given proper weights. Cost figures enable supervisory personnel to find where savings can be made. Proper plotting of monthly sewage costs and budget allowances gives a continuous picture of efficiency and shows variations caused by season, population, or other factors.

a. Procedures. Cost-accounting procedures are given in TM 5–602. The code of accounts which defines account numbers and base units should be followed carefully by all personnel so labor and materials are charged to the proper account and true costs reflected.

b. Base data. Base data from which unit costs are computed must be accurately determined and corrected when extensions or changes are made. The base data should agree with operating reports where applicable.

18. Preventive Maintenance

Systematic inspection and maintenance permits early correction of faults before major defects and failures develop. Operation and maintenance are closely related This manual and TM 5-666 supplement each other and are to be used together; references to TM 5-666 are used freely throughout the text.

19. Operating Reports

Detailed reports of operation are necessary to evaluate plant performance. Daily records show the operator what his plant is doing while monthly summaries are used for comparison of current and past performances. Accumulated reports for long periods of time show variations caused by changes in population, seasons, methods of operation, and other factors. Accumulated records are the best basis for evaluating a given process or method of operation. A given procedure should be continued for a month or longer to produce a reliable operation record. Accumulated records form an excellent basis for designing plant extensions. Because standard design bases for Army plants cannot anticipate local conditions, local operating records often show how extensions to existing plants can be made more economically.

20. Daily Logs

Keeping certain daily logs assists the operator in maintaining efficient operation and forms a basis for preparing required monthly logs. For example, the monthly log calls for the total volume of screenings and grit removed and total gallons of sludge drawn to beds. This can be determined only from daily records.

21. Monthly Operating Logs

WD AGO Forms 5-60 and 5-61 are sewage operating logs. They are posted daily at the treatment plant and are completed and signed by the operator and post engineer monthly. The original is filed at the treatment plant for operating reference and copies are forwarded to higher authority for technical review.

a. WD AGO Form 5-60 (fig. 6). Form 5-60 is used by all stations provided with sewage treatment plants, other than septic tanks.

b. WD AGO Form 5-61 (fig. 7). Form 5-61 supplements Form 5-60 at stations with secondary sewage treatment or large primary treatment plants with separate sludge digestion where detailed analysis is justified.

c. Instructions. Specific instructions for each column are given on the back of the form. Data must be posted carefully to avoid mistakes.

22. Records and Maps

Records and maps of utility features above ground can be reproduced easily, but tracing and locating underground features is difficult and time consuming. Because records of hidden contruction cannot always be replaced, existing records and maps of sewerage systems should be carefully preserved and inaccurate ones should be corrected.

a. Records and plans. A complete set of records and plans of the sewerage system and sewage treatment plant are filed at the plant or in the post engineer's office. The records include the following:

(1) Dates of installation and major additions.

(2) Data on design and capacity of sewers, pumping stations, and treatment plant.

(3) Pump data, including manufacturer, type, size, capacity, and head.

(4) Manufacturer's data on all installed mechanical equipment.

(5) File of test and operating records.

(6) Maintenance records required by TM 5-666.

b. Maps. Maps showing the over-all sewer system and sectional plots showing more detailed information are necessary.

(1) The general sewerage map shows the entire system in bold lines whose widths are in proportion to sewer sizes. For large installations, a scale of 1 inch equals 400 feet or 1 inch equals 300 feet is used. For smaller installations, the scale may be 1 inch equals 200 feet. Detail on the general map should show the pipe system with pipe sizes, connections, manholes, pump stations, force mains, and directional-flow arrows.

(2) The detailed utilities maps are made available to the field crews. Scales of 1 inch equals 100 feet or 1 inch equals 50 feet are used. The following details are included:

(*a*) Manhole locations with reference points.

(*b*) Manhole invert and cover elevations.

Control Approval Symbol
EMU-68

SEWAGE OPERATING LOG

POST ____________________ MONTH ENDING ____________________ 194____

LOCATION ____________________

	No.	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total	Average	Max.	Min.
		Date																																			
		Day of week																																			
WEATHER	1	Rainfall, inches																																			
WEATHER	2	Wind direction																																			
WEATHER	3	Air, temperature, °F.																																			
	4	Stream flow																																			
	5	Temp. plant influent, °F.																																			
	6	pH plant influent																																			
	7	pH primary effluent																																			
SEWAGE FLOW (1,000 Gal.) — RATE OF FLOW	8	Maximum - 1000 gal./day																																			
SEWAGE FLOW (1,000 Gal.) — RATE OF FLOW	9	Minimum - 1000 gal./day																																			
SEWAGE FLOW (1,000 Gal.)	10	Total treated - 1000 gal.																																			
SEWAGE FLOW (1,000 Gal.)	11	Total bypassed - 1000 gal.																																			
SEWAGE FLOW (1,000 Gal.)	12	Total recirculated - 1000 gal. From ______ To ______																																			
ANALYSIS — SETTLEABLE SOLIDS ml./liter	13	Raw																																			
ANALYSIS — SETTLEABLE SOLIDS ml./liter	14	Primary effluent																																			
ANALYSIS — SETTLEABLE SOLIDS ml./liter	15	Final effluent																																			
ANALYSIS	16	D.O. Final Effluent p.p.m.																																			
ANALYSIS	17	Relative Stability final effluent, %																																			
REMARKS		(Include unusual sewage or creek flows, operating troubles, complaints, special analysis, etc.)																																			

18. Screenings and Grit Removal.	Total cu.ft. removed	Manner disposal
Screenings		
Grit		

19. Digested Sludge Data	
Total gallons drawn to beds	
Average pH	
Av. % Solids	
Av. % Volatile Solids	
Cu.Yds. sludge removed	
Av. drying time, days	

20. Depth of sludge below Imhoff Tank slots - Ft.

Date	Sampling Point					

21. Per capita sewage flow _____ gallons per day.

Prepared By ____________________ Date ______
(Operator)

Approved By ____________________ Date ______
POST ENGINEER

W. D., A. G. O. FORM No. 5-60
4 July 1944
(This form supersedes W. D., O. C. E. Form No. 440, Sec. F, which may be used until existing stocks are exhausted.)

FIGURE 6. *Sewage operating log, WD AGO Form 5-60.*

Control Approval Symbol
SPO-68

SEWAGE OPERATING LOG

POST ______________________ MONTH ENDING ______________________ 194__

LOCATION ______________________

	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total	Aver.	Max.	Min.	Remarks
	Day of Week																																				
Raw Sludge	1. Gallons Pumped																																				
Raw Sludge	2. Percent Solids																																				
Raw Sludge	3. Percent Volatile																																				
Analytical Results — B.O.D. (5 Day) p.p.m.	4. Raw																																				
Analytical Results — B.O.D. (5 Day) p.p.m.	5. Primary Effluent																																				
Analytical Results — B.O.D. (5 Day) p.p.m.	6.																																				
Analytical Results — B.O.D. (5 Day) p.p.m.	7.																																				
Analytical Results — B.O.D. (5 Day) p.p.m.	8. Final Effluent																																				
Analytical Results — Suspended Solids p.p.m.	9. Raw																																				
Analytical Results — Suspended Solids p.p.m.	10. Primary Effluent																																				
Analytical Results — Suspended Solids p.p.m.	11.																																				
Analytical Results — Suspended Solids p.p.m.	12.																																				
Analytical Results — Suspended Solids p.p.m.	13. Final Effluent																																				
	14.																																				
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24. MONTHLY DIGESTER ANALYSIS DATE

No. 1					No. 2			
Depth (feet)	Temp °F.	pH	% Sol.	% Vol.	Temp °F.	pH	% Sol.	% Vol.

25. Average Percent Removal

Unit	% B.O.D.	% Susp. Solids
Pri. sedimentation		
Sec. treatment		
Total		

26. WEEKLY STREAM ANALYSIS

Date	1. Above Outfall ______ Miles			2. Below Outfall ______ Miles			3. Below Outfall ______ Miles		
	B.O.D. p.p.m.	D. O. p.p.m.	D. O. % Sat.	B.O.D. p.p.m.	D. O. p.p.m.	D. O. % Sat.	B.O.D. p.p.m.	D. O. p.p.m.	D. O. % Sat.

W. D., A. G. O. FORM NO. 5-61
3 JULY 1944
(THIS FORM SUPERSEDES W. D., [illegible] FORM NO. [illegible], WHICH MAY BE USED UNTIL EXISTING STOCKS ARE EXHAUSTED)

FIGURE 7. *Sewage operating log, WD AGO Form 5-61.*

(*c*) Distance between manholes.

(*d*) Sewer material, sizes, and grades.

(*e*) Location and size of house laterals (distance of wye from manhole).

(*f*) Location of all storm-water inlets or connections to storm sewers or catch basins.

(*g*) Location of force-main air reliefs and drain sumps.

(3) Maps should be kept up to date by correcting for changes and additions. In making these corections, location of manholes covered by roads and grounds maintenance may be determined by a probing bar, dip needle, or transmitter-receiver type pipe locater. House-sewer lines, wyes and abandoned sewers can be located by inserting a steel tape or plumber's snake into the sewer, energizing the steel, and using the receiver pipe locater.

23. Operating Precautions

Safety measures for inspection, operation, and maintenance of sewerage systems are effective if the hazards are known and proper methods of avoiding them are used. Personnel must recognize hazards and cooperate with the post safety director on safety programs established by current directives. A publication by Federation of Sewerage Works Association, Occupational Hazards in the Operation of Sewage Works, Manual of Practice No. 1, is to be used also.

a. Classes of hazards. Sewage plant and sewer system operation is subject to the following classes of hazards:

(1) Bacterial infection.

(2) Mechanical.

(3) Gas.

b. Prevention of body infections. Constant vigilance is necessary to prevent infection.

(1) Adequate toilet and washing facilities which help prevent infection should include wash bowls supplied with hot water, liquid or powdered-soap containers, paper towels, and shower baths.

(2) Sewage and sludge on the hands contaminate doorknobs and fixtures. Dirty clothing or careless washing of hands may spread infection beyond the sewage treatment plant area.

(3) Emergency first aid must be *promptly* given to all minor cuts, burns, and injuries. Major injuries must be treated by a medical officer at once.

(4) Employees are inoculated for typhoid and paratyphoid fever yearly as required for military personnel. Special precautions with disinfectants and inoculations prescribed by the post surgeon are taken when intestinal diseases and infection are prevalent.

(5) When hands are chapped, burned, or the skin is broken, rubber gloves are worn to prevent infection while handling screenings, sewage, sludge, or other filth. Fingers must be kept out of the nose, mouth, and eyes.

(6) After work and before eating, personnel must wash the hands thoroughly with plenty of soap and hot water. Fingernails are kept short and clean.

(7) Contact of hands with sewage or liquid sludge is avoided if possible.

(8) Drinking water from laboratory glassware or eating lunch in the laboratory is prohibited.

c. Protection against mechanical hazards.

(1) Many danger spots around a sewage plant require fencing, railings, or other protective devices to safeguard the operator against manholes, scum chambers, and open tanks. Stairways must have railings.

(*a*) Tools must be picked up, manhole covers promptly and carefully replaced, and every effort made to promote good housekeeping.

(*b*) Protective guards must be provided and maintained about all moving parts such as clutches, couplings, and bolts on flywheels which catch clothing.

(*c*) Lubrication or adjustments are not made on machinery in motion which is not fully inclosed or otherwise adequately guarded.

(*d*) Care must be taken in maintenance or repair work on automatic or remote-control equipment to insure that power is disconnected so equipment cannot be started accidentally. Removing all fuses, using a fuse puller, or padlocking switch in open position must be done to insure safety. A warning tag is attached to the switch; these tags are kept convenient for ready use.

(*e*) Floors are kept clean and dry to prevent slipping.

(*f*) No cleaning solvent with flash point below 100° F. is used, which prohibits use of gasoline, naptha, or benzine. For precautions in using other solvents see TM 5–666.

(*g*) Where internal combustion engines are provided for regular or standby power, precautions are taken against deadly carbon monoxide fumes by periodically checking gaskets and bolts in manifolds, mufflers, and exhaust lines. Exhaust must discharge to exterior and fuel tanks vented to outside. Crane-case breathers are vented outside the building or to intake manifold. Adequate room ventilation is provided.

(2) Sewer maintenance, except for repairs, must be performed through manholes often located in streets.

(*a*) Heavy manhole covers are removed and replaced carefully with proper tools to avoid injuries to fingers and hands.

(*b*) Manhole steps are used cautiously because they are often slippery or weakened by corrosion.

(*c*) Men entering deep sewers always wear an approved safety belt with life line. At least two men must remain outside to handle the life line.

(*d*) Barriers and warning signs are placed far enough from open manholes to warn traffic.

d. Protection against gas hazards. Gases and fumes found at sewage treatment plants and in sewers may cause serious fires, explode when mixed with certain proportions of air, or asphyxiate (cause a reaction similar to drowning), or poison men exposed to them. In addition to these gases, digester gas and chlorine gas must be safely controlled. Gases in sewers may come from decomposing organic matter but more often are from domestic-gas leaks or volatile liquids discharged to the sewers by repair shops or industrial plants. Such disposal is prohibited. Sewers and pits may be free from harmful gases yet dangerous because of oxygen deficiency. Tests before entering should be made with explosimeter and oxygen-deficiency lamp. Artificial ventilation is provided where improper atmosphere is found.

e. Digester gas. The gas from digesting sewage sludge is inflammable, explosive when mixed with certain proportions of air, asphyxiating, and sometimes toxic.

(1) Personnel are not permitted to enter a partially drained sludge-digestion tank without a hose mask or self-contained oxygen-breathing apparatus unless the tank has been purged of gases by forced ventilation and tested with explosimeter and oxygen-deficiency lamp. A life line is attached to the man before he enters while at least two men remain outside to handle the line.

(2) Smoking is prohibited near open manholes or in inclosed spaces where digester gas may be present. Only approved explosionproof motors, lights, and electrical fixtures are permitted in these places.

(3) All safety devices for gas handling such as flame traps, pressure reliefs, automatic pilots, and all gas lines must be inspected periodically according to instructions in TM 5–666. All relief vents from such equipment must be outside of inclosed spaces. Nonsparking tools are recommended when opening manhole covers or making repairs where gas may exist. Rubber overshoes should be worn entering tanks, manholes, or other danger areas.

f. Chlorine (*see also* par. 146). Chlorine is heavier than air and settles into low places along floors and into pits; it is extremely irritating to the eyes, mouth, throat, and nose. Strong solutions injure skin and clothing. The following precautions must be observed:

(1) Only reliable and trained men handle chlorine.

(2) Containers cannot be bumped or dropped.

(3) Protective valve caps are kept on containers not in use.

(4) Chlorine valves are opened carefully with a proper wrench. They are opened only part way. Tapping wrench lightly aids in operating stuck valves. Extension on wrench is never used. Cylinder valves are closed when not withdraw'ng chlorine and when empty.

(5) The cylinder is never used for any purpose other than chlorine gas.

(6) Slightest leak of chlorine gas is given immediate attention. Leaks may be located by passing an unstoppered bottle of strong ammonia solution along chlorine lines and around fittings, connections, and valves; white fumes of ammonium chloride indicate a leak. Ammonia solution cannot be applied to plated metal parts, because it will remove the plating.

(7) Gas masks with suitable canister must be provided for at least two persons and worn when personnel are subjected to chlorine gas. Gas masks are kept in an accessible place not subject to gases. Personnel must be instructed in their use.

Note: Precaution prevents accidents—Carelessness kills men.

CHAPTER 2
SEWAGE COLLECTION SYSTEMS

24. Sanitary Sewers

The sanitary sewage collection system includes all house sewers, laterals, branches, interceptors, force mains, manholes, and sewer appurtenances from buildings to treatment plant and point of final discharge.

25. Storm Sewers

The storm sewer system includes all laterals, branches, interceptors, force mains, outfalls, catch basins, manholes, and appurtenances, from the inlets to the point of discharge. It does not refer to ditches, culverts, or open-joint tile drains for subsurface field drainage, although the latter may discharge to the storm sewer system. Storm sewer systems are kept separate from sanitary sewage collection systems because the large sewer sizes required for storm flow do not provide adequate velocity for sanitary sewage in dry weather and treatment of storm water is not required. Sewer-cleaning methods in this chapter and in TM 5–666 apply to both storm and sanitary sewers. Other methods of maintaining, repairing, and extending sewers are given in TM 5–624 (when published).

26. Operation and Maintenance

The sanitary system should always remove sewage from the building areas without insanitary overflow and odor nuisance. It should deliver sewage to the treatment plant as fresh as possible; poor sewer conditions cause many difficulties in sewage treatment.

a. Grease and trash. Improper installation or cleaning of grease traps in mess halls frequently clogs house sewers and laterals. (See par. 28.) Larger sewers seldom become plugged, but a heavy grease coating may reduce flow capacity. If collected grease, garbage, and trash are dumped in manholes by mess personnel, the offense is reported for corrective action. Manhole covers near mess halls may be secured by bolts or cement grout between the rim and frame to make access more difficult. Cooperation between post salvage officer, company commanders, and the sanitary officer is often necessary to prevent misuse of the sewer system.

b. Roots. Tree roots, especially those of rapid-growing trees, penetrate cracks in sewer joints and form root masses in the sewer. This can be prevented by sheet-copper rings in the joints or by bituminous or asphaltic joint materials. Rapid-growing trees should not be planted near sewers, and in extreme cases, removal of existing trees is warranted. Methods of root removal are given in paragraph 30.

c. Sewer misalignment. Sewers and manholes in unstable soil may settle or float upwards to form pockets in which solids deposit. The only remedy is relaying the line with adequate support. Misalignment is determined by lamping, flashing light from a mirror or explosionproof electric lamp through the sewer between manholes.

d. Sand and grit. Deposits of sand and grit causing sluggish flow may come from surface inlets which should be connected to storm sewers or ditches, perforated manhole covers set too low, or broken or open-jointed sewer pipes.

e. Stale sewage and odors. Obstructions in the sewer cause deposition or entrainment of sewage solids. Anaerobic decomposition occurs, resulting in stale, septic sewage which is more difficult to treat than fresh sewage and creates odor nuisances. Odor may also be caused by growths of sulfate-reducing bacteria which produce hydrogen sulfide gas.

27. Inspection

The labor needed to keep a sewer system in operation depends upon design construction, and use. Misuse of the sewers can be kept at a minimum by frequent and careful inspection. Inspections are made in accordance with TM 5–666.

28. Grease and Oil Traps

a. Inside grease traps. Grease interceptors installed inside mess halls are normally cleaned by the mess personnel. Proper methods for installing and cleaning are given in TM 5–619 (when published). Inside traps are cleaned daily as follows:

(1) Skim congealed and liquid grease from surface of water. Place grease in separate container for salvage.

(2) Take all removable baffles from interceptor and wash them with stiff brush.

(3) Clean all solids from bottom of interceptors with any ordinary strainer. Put solids in a garbage can.

(4) Inspect flow-control orifice for clogging.

b. OUTSIDE GREASE TRAPS. Post engineer personnel are usually responsible for cleaning large concrete grease traps located outside mess halls. Accumulated putrescible solids cause spetic action in these traps. Solids must be removed each time the traps are cleaned. Complete cleaning chould be performed once a week as follows:

(1) Skim off grease and place it in containers for salvage.

(2) Remove most putrescible solids with same scoop used for removing grease.

(3) Remove any obstruction in outlet pipe.

(4) At 3-month intervals, pump liquid contents from traps and remove all sediment from walls and bottom.

(5) Do not spill grease and organic solids on ground around trap.

c. OIL INTERCEPTION. Signs of gasoline, lubricating oils, or grease in sewers must be traced to their source. Oil interceptors are installed in drains from garage and shops where greasy wastes are discharged. Regular cleaning is necessary. To avoid explosions, discharging gasoline, kerosene, and other volatile liquids to sewers is *strictly prohibited.*

29. Infiltration and Storm Water

a. INFILTRATION. Infiltration is seepage of ground water into the sewer system through sewer joints or cracked pipe. Amount of infiltration depends upon the tightness of the sewer joints, ground-water level, and soil porosity. In reasonably tight systems laid below ground-water level, infiltration should not exceed 10,000 gallons per day per mile of sewer. Excessive infiltration may overload the sewer system and treatment plant. Major sources are located by observation of comparative flow at manhole during low flow periods, and the sewer is repaired at such points. Extensive repairs are made only when extreme conditions exist. At posts not fully activated, infiltraction may help keep sewers clean and fresh.

b. STORM WATER. Storm water entering sanitary sewers from roof drains or surface inlets and perforated manhole covers at low-surface grades may overload sewers during heavy rains. Such flows may also exceed the hydraulic capacity of sewage pumping and treatment plants, requiring bypassing of sewage without treatment. Under such conditions, sources of storm water should be found and corrected.

c. DETERMINING AMOUNTS. The amount of infilteration can be readily determined at Army posts by comparing average sewage flows during active and inactive periods. These comparisons must be made for the same seasons of the year to allow for seasonal fluctuation of ground-water level. Volume of minimum night flow may also be a factor. Stormwater flow is determined by comparing daily flows during wet and dry days, the amount usually being proportional to the rainfall. Rainfall measurements are obtained as shown in TM 5–660 (when published) and entered on the monthly operating log, WD AGO Form 5/60.

30. Methods of Sewer Cleaning

Observe safety precautions given in paragraph 23 for explosive, toxic, or asphyxiating gases before entering manholes. Ventilate where necessary. Use safety belts and ropes. Place warning signs around manholes in roadways. Close manhole covers after use. Periodically flush and clean sewers in accordance with schedules contained in TM 5–666.

a. FLUSHING. Loose organic solids and sand or grit deposits can be removed by several flushing methods. To be effective, high-flushing velocity must be maintained to prevent redeposit of solids. Simple flushing with a fire nozzle in a manhole is not as effective as commonly believed. The following methods normally are used:

(1) *Fire hose.* Use enough fire hose to reach between manholes. First, string a rope or light cable through the sewer with sewer rods if a plain fire nozzle is used, starting at the upper ends of the system, and draw the flowing nozzle through the sewer. If a self-propelling turbine type nozzle (fig. 8) is used, the rope is not required. Use 2-inch fire hose discarded by the fire department if possible. Paint sewer-flushing hose at ends with an identifying color to prevent use for emergency potable-water connections. Because this method wastes large quantities of water, methods below are preferable.

(2) *Pneumatic-ball method.* Inflate a light rubber ball, such as a beach-ball or volley-ball bladder to fit snugly in the sewer, and place it in a small canvas or burlap bag with a light rope attached. Place ball in sewer, hold line until the sewage backs up in the manhole, and allow ball to move to next manhole. When an obstruction is reached, the pressure presses the ball against crown of the sewer, causing a jet at the invert or bottom. (See fig. 9.) As much as 4 miles of sewer can be cleaned in 8

hours by this method, which works for sewers up to 30 inches in diameter. A wooden ball with a diameter 1 inch less than the sewer may also be used. Where sewage flow is low, addition of water to the upper manhole may be required.

(3) *Sewer hoe or scooter.* The hoe and scooter are similar in action to the ball method. The sewer hoe (fig. 10) is a homemade device, suitable for sewers over 30 inches in diameter. The sewer scooter is an improved commercial device for 8-inch to 24-inch sizes. Figure 11 shows the scooter pushing debris ahead and flushing action with the shield collapsed.

(4) *Sand cup.* A perforated rubber diaphragm called a sand cup is available for attachment to flexible-steel sewer rods. Its action is similar to above devices. (See fig. 12.)

(5) *Automatic or constant-flow devices.* Automatic or constant-flow flushing devices cannot be installed unless specifically authorized for special latrines in a minimum water-borne sewerage system. Such installations are not used because of cross-connection hazards with the potable water supply, wasting of water, and unnecessary use of critical material. Installations now in use must be removed and the water connection severed permanently at the main.

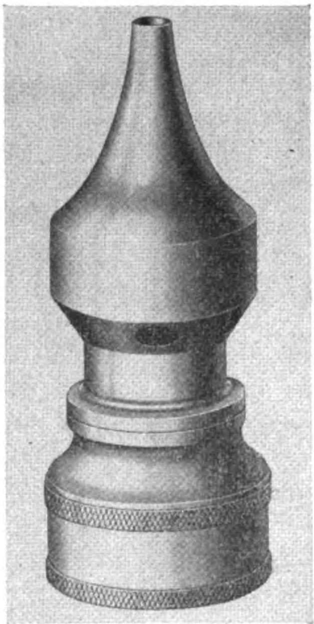


FIGURE 8. *Self-propelling turbine type nozzle for sewer flushing.*

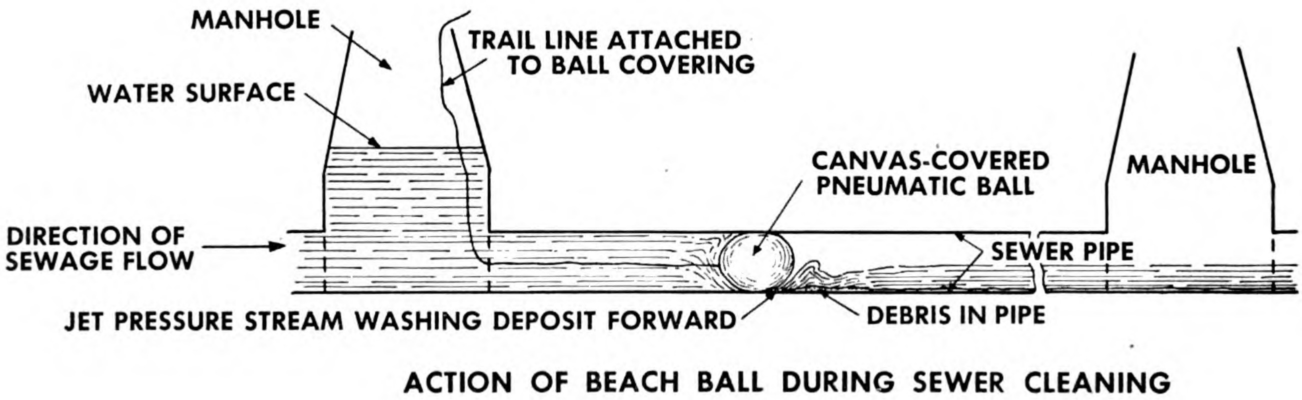


FIGURE 9. *Ball method of sewer flushing.*

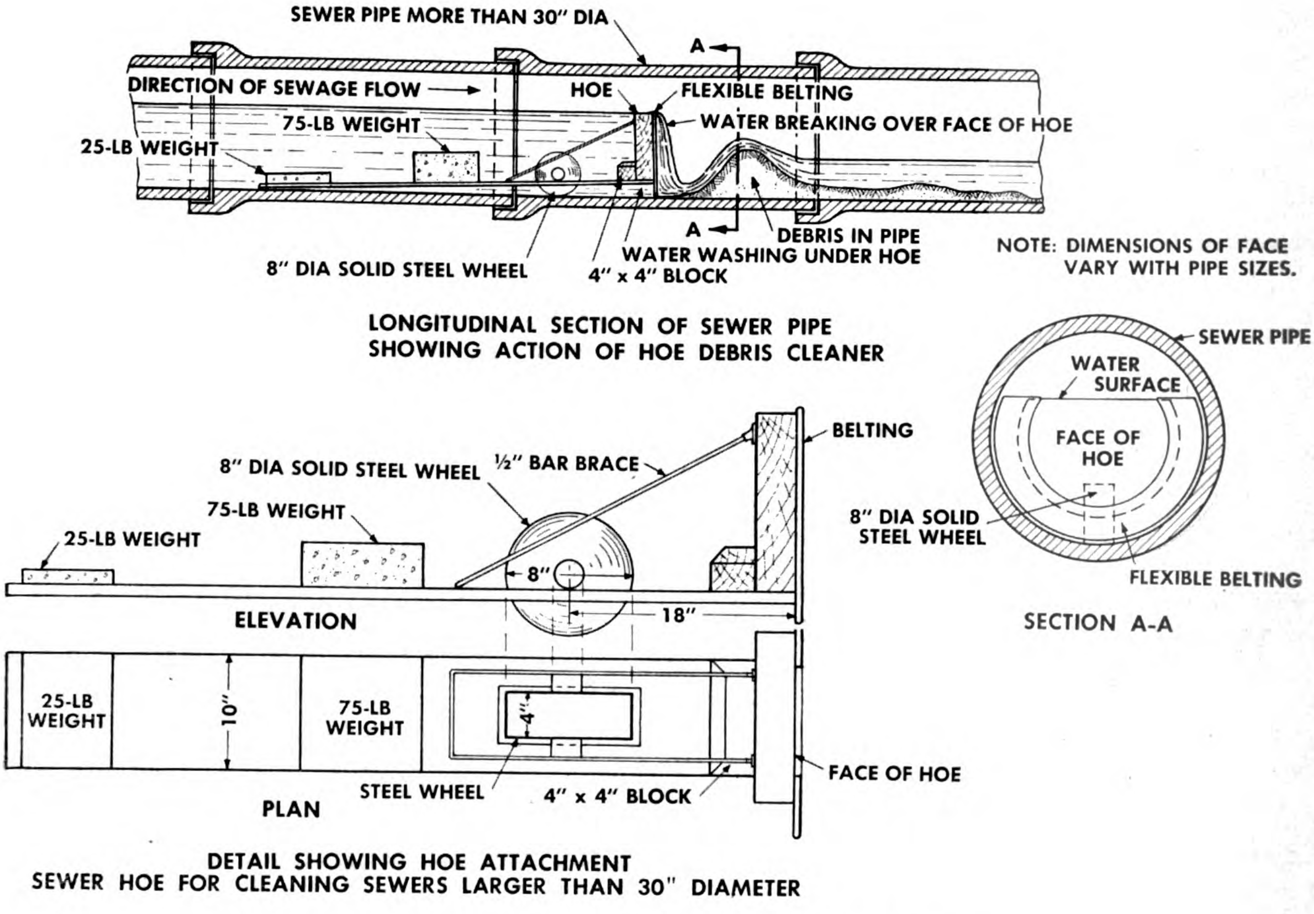
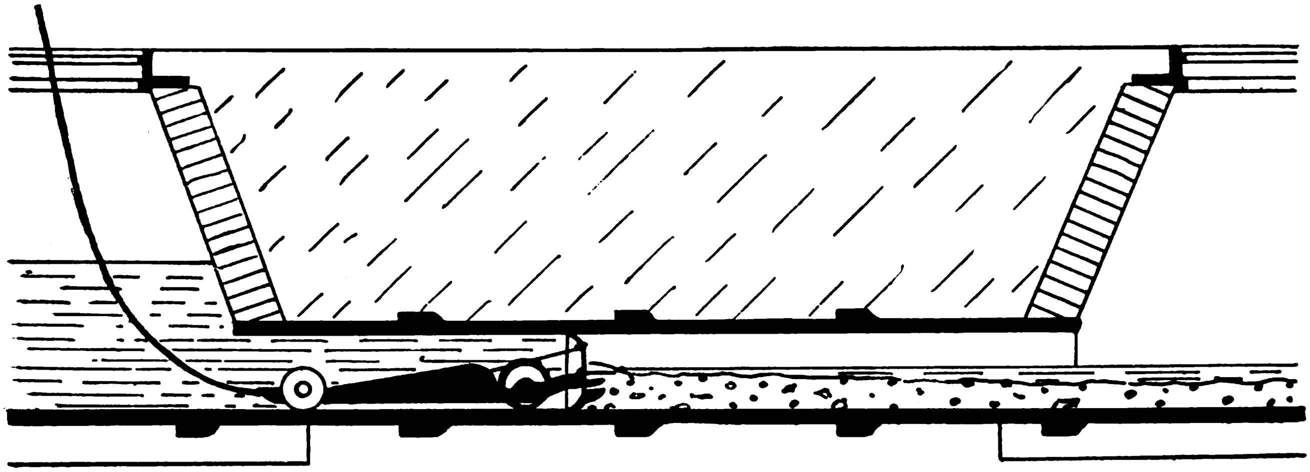
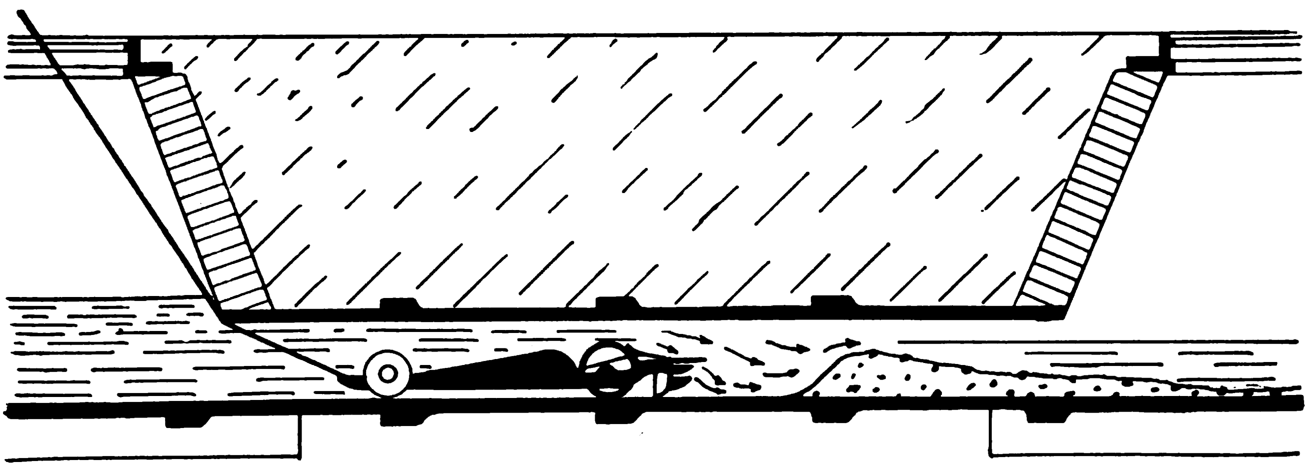


FIGURE 10. *Sewer hoe for flushing sewers over 30 inches in diameter.*





① Water pressure on shield pushes debris forward.
② Upper half of shield pulled back by cable to flush debris.

FIGURE 11. *Sewer scooter.*

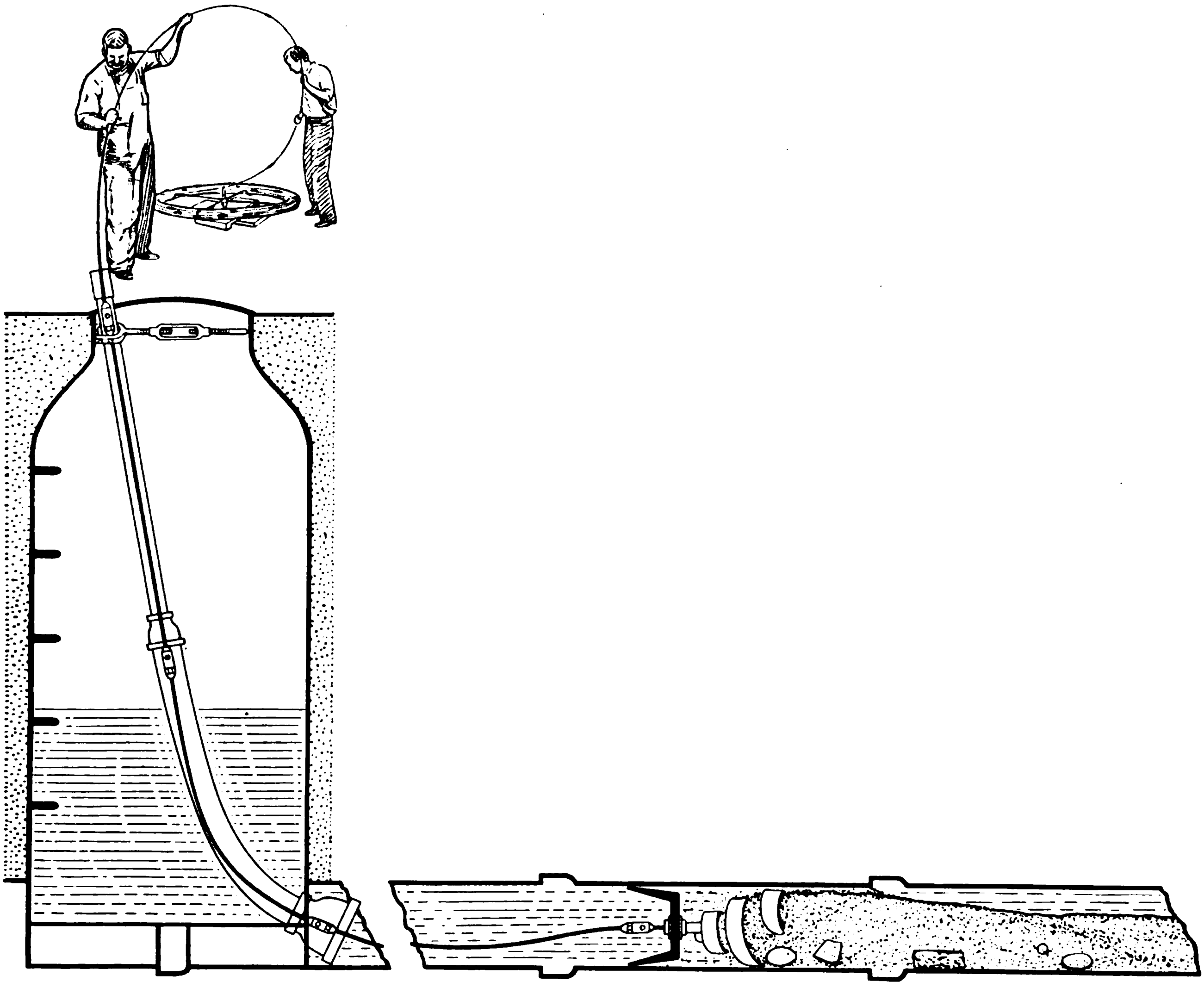


FIGURE 12. *Sand cup with auger used with flexible-steel rods. Rubber cup is perforated to provide flushing action.*

b. Sand removal. (1) The flushing methods described above remove all but heavy sand deposits. Accumulated sand and grit dislocated by flushing should be removed from the sewer at a manhole. A sand trap, made from stove-pipe ell and sheet metal to fit the sewer pipe, may be used, as shown in figure 13, to collect the sand. Commercial traps are available with adjustable slots to lower the water level below the top of the trap. Sand is removed by scoops or buckets.

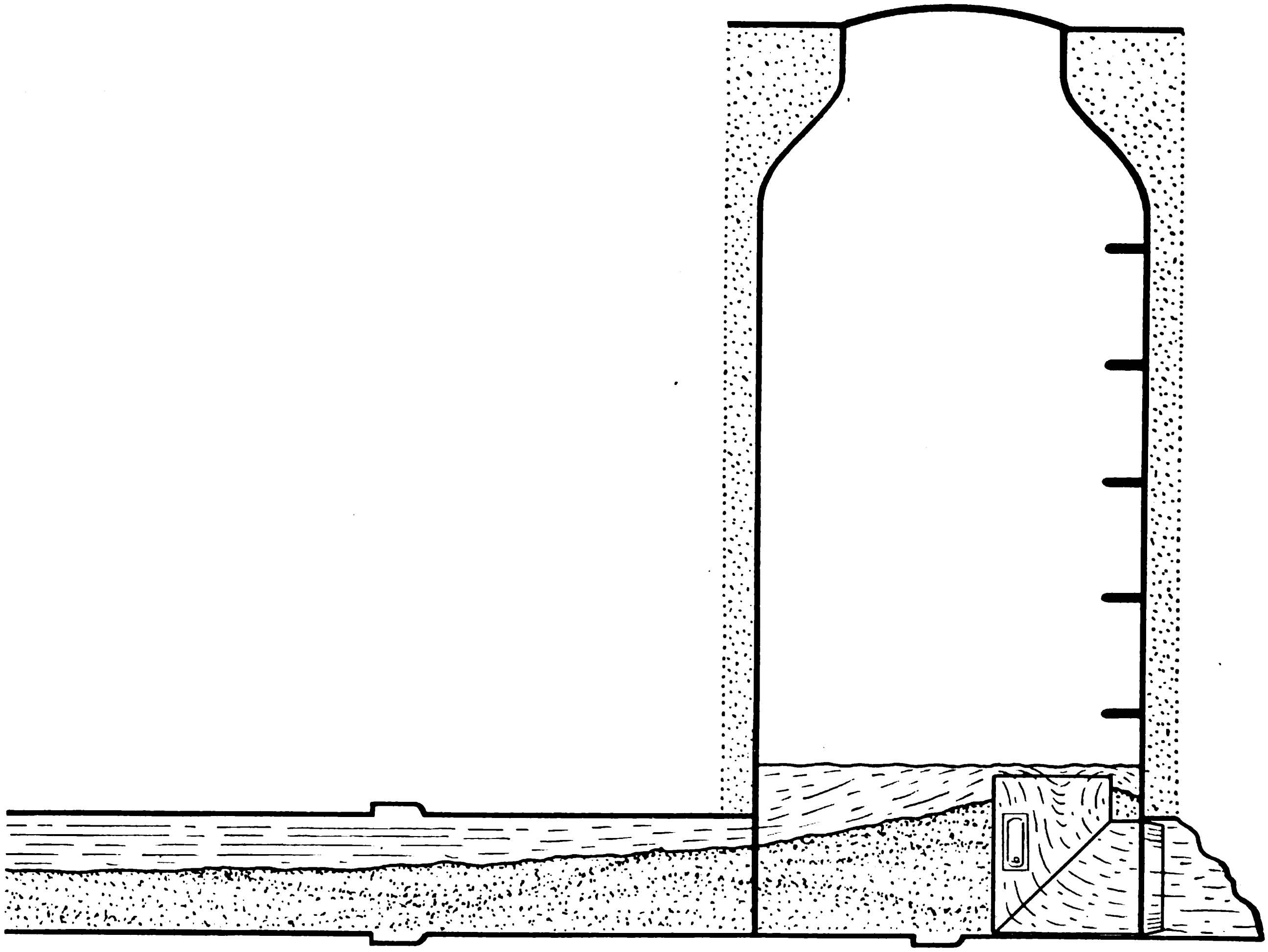


Figure 13. *Sand trap.*

(2) For heavy deposits, a cable-drawn bucket is used, especially for storm sewers and larger sanitary sewers. The cable may be pulled by hand (fig. 14), power winch (fig. 15), or by a truck with the cable through an anchored sheave. Damage to the sewer may occur if the bucket catches on misaligned joints, improper house connections, or other fixed obstructions. This is especially true for power-driven buckets.

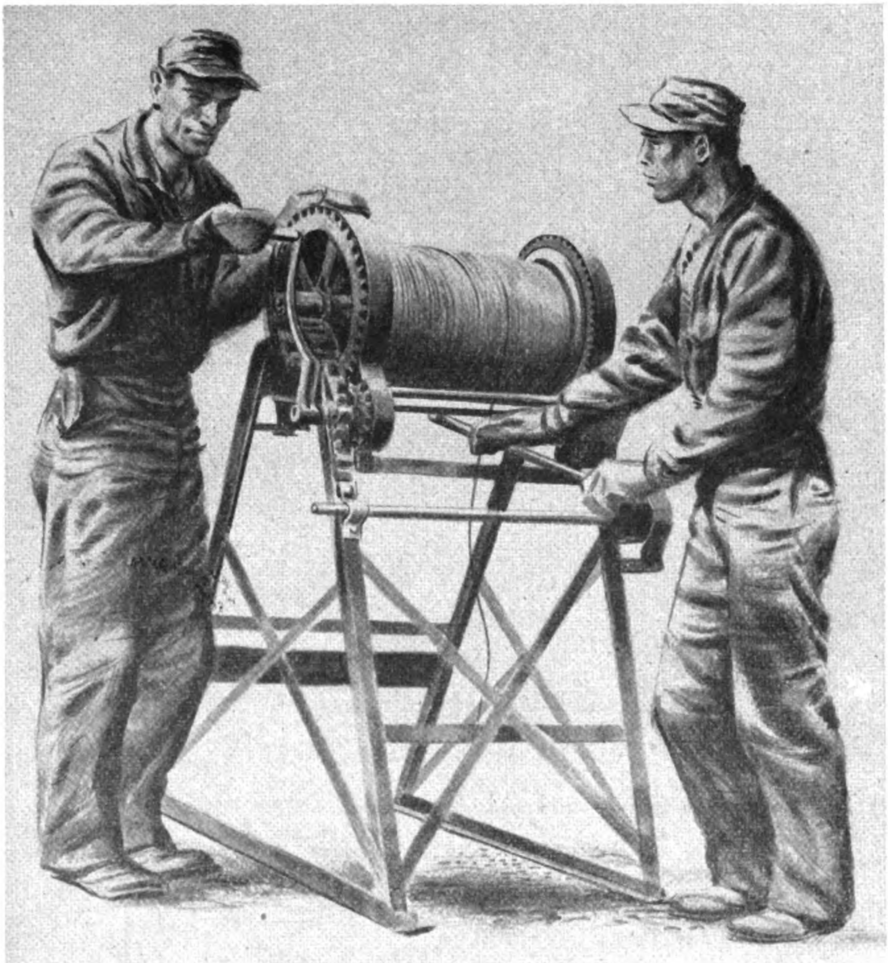


FIGURE 14. *Hand winch for cable-drawn tools.*

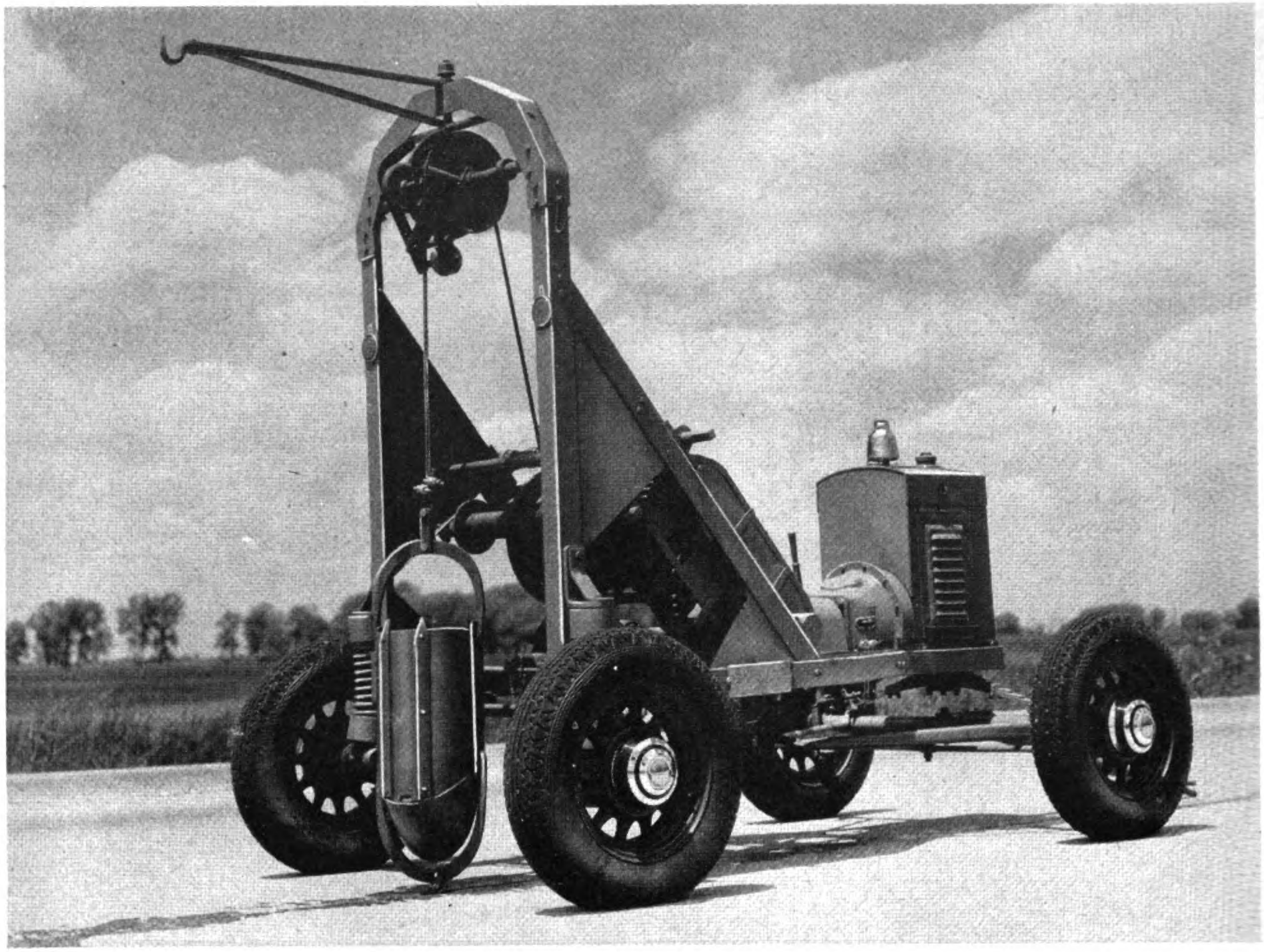


FIGURE 15. *Powered winch with bucket, particularly suited for storm-sewer cleaning.*

c. OBSTRUCTION REMOVAL. A variety of tools are available for clearing sewers of partial or total obstructions.

(1) *Wooden sewer rods.* Sectional wooden sewer rods equipped with end tools have been used for many years. End tools for initial piercing of an obstruction and cutters and scrapers for root and grease removal are available. Rods are pushed into the sewer from the bottom of a manhole. A pushing device (fig. 16) is useful. Wooden rods are particularly useful to string a cable through a partially obstructed sewer.

(2) *Flexible-steel rods.* Light-weight spring-steel sectional rods are available from several manufacturers. They are coupled into a continuous line with several types of augers and sand cups used as end tools. The tool and rod is pushed into the sewer, and the obstruction removed by twisting the

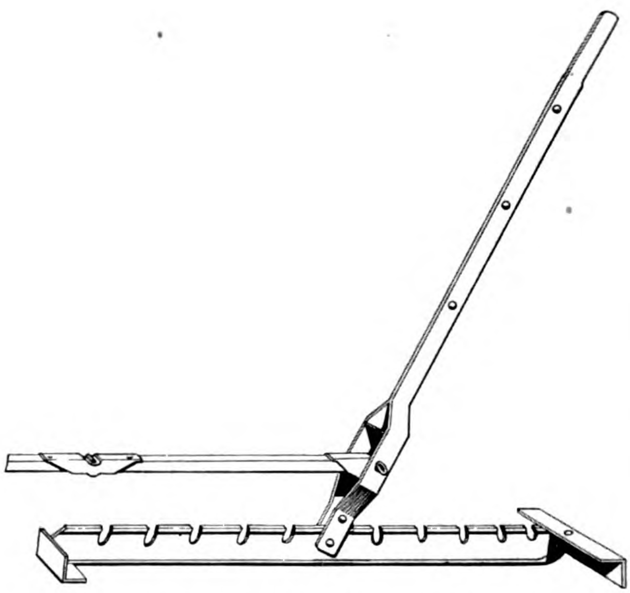


FIGURE 16. *Pushing device for wood sewer rods.*

rod. Figure 17 shows root removal with the rod turned by hand; a small gasoline-engine drive is also used. (See fig. 18.) Because these rods are pushed and turned at the surface instead of the bottom of the manhole, they are less hazardous. Sewers can be cleaned much more rapidly with these rods than with other types of equipment, and their use is recommended to reduce labor costs.

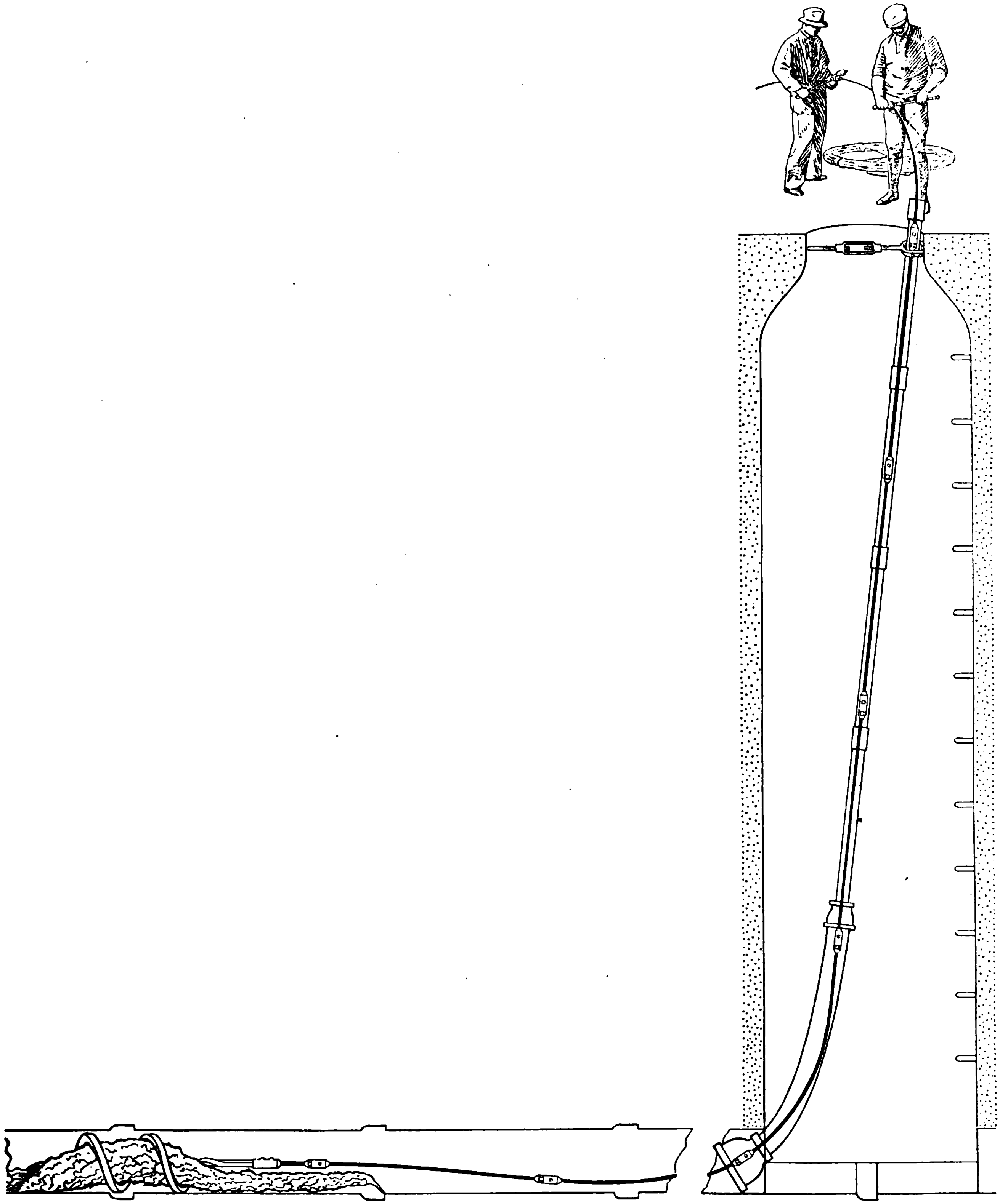


FIGURE 17. *Root removal by steel rod and auger, manual operation.*

FIGURE 18. *Operation of steel rods with power drive.*

(3) *Turbine type tools.* Turbine cleaning tools are powered by water under pressure from a fire hose and carry revolving knives or wire brushes. (See fig. 19.) The tool and hose is pulled through the sewer by cable. They are particularly useful for removing grease coatings and small tree roots.

(4) *Scrapers.* Several types of cable-drawn scrapers are used, some of homemade construction. (See fig. 20.) They are used for the same purposes as turbine type tools.

d. USE OF COPPER SULFATE. Copper sulfate (blue vitriol) is effective in root removal and control of sulfur-reducing organisms which cause hydrogen sulfide odors and stale sewage. Because the chemical may arrest sludge digestion at the sewage treatment plant, it must be used with caution. Decreased digester-gas production for a period longer than 1 week after use indicates excessive copper sulfate application has been made; subsequent treatment is made with reduced quantities of the chemical, or other methods of root removal are used.

(1) *Root removal.* Copper sulfate slowly kills the root, which breaks free. It can only be used where the obstruction is not severe because 1 to 3 weeks

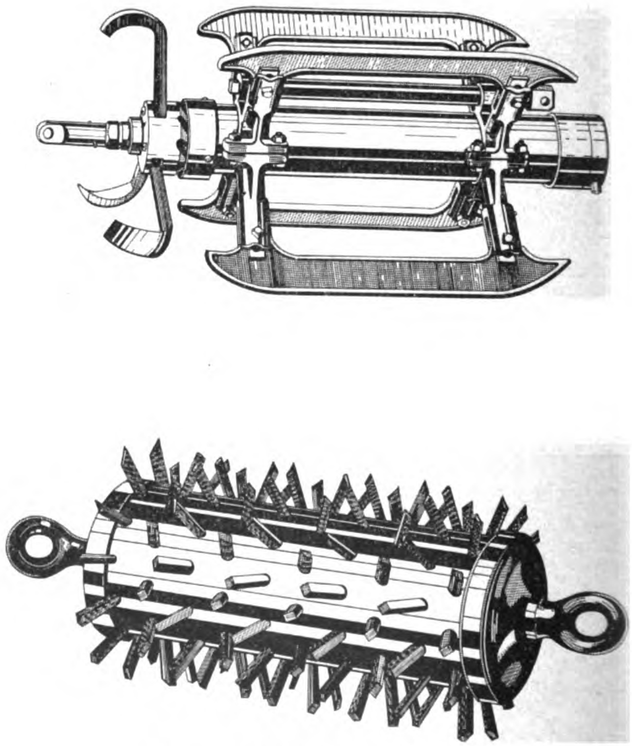


FIGURE 19. *Turbine-driven tools.*

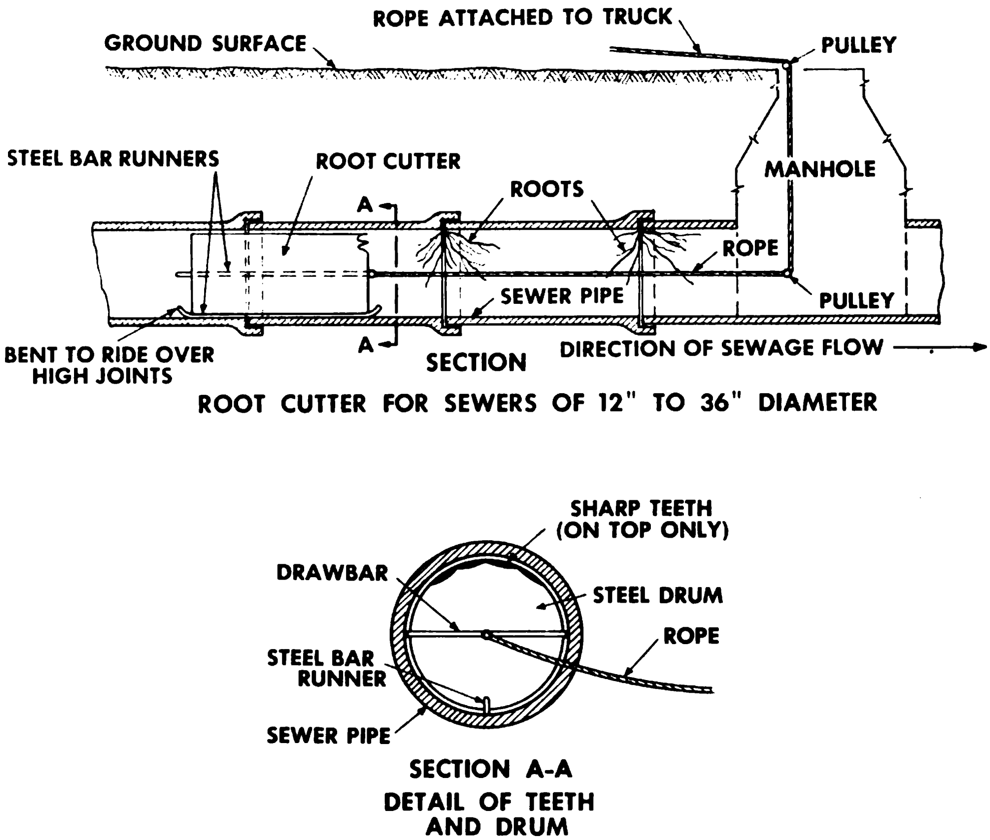


FIGURE 20. *Homemade scraping and root-cutting tools, cable drawn.*

may elapse before the root is killed. The method is best used for house sewers, not readily cleaned by tools, by flushing copper sulfate crystals from a toilet bowl. For lateral and branch sewers, drop 2 or 3 pounds in the manhole above the root growth. Do not repeat the dose within 30 days. If root growths are prevalent throughout the system, dose with copper sulfate on a single day, at the minimum possible number of points (upper ends of system or house connections). Do not repeat widespread treatment within 3 months.

(2) *Hydrogen sulfide control.* Copper sulfate applied to sewers at 1-year to 6-month intervals destroys sulfate-reducing growths. Continuous chlorination of the sewage at one or more upper manholes accomplishes similar results but is more expensive. Lime and iron salts are also used for hydrogen sulfide control, but do not prevent its formation. A dose of 5 ppm of copper sulfate is adequate with ample contact period; a dose of 50 ppm is recommended for sewers because of the short contact period. Treat during peak flow to permit contact with growths above normal flow line. Calculate the total dose for the 1-hour peak flow according to the following example.

1.800 (peak flow, mgd) $\div$ 24 (hours) $\times$ 8.3 $\times$ 50 (ppm) = 31 (lbs.)

Place the copper sulfate in uppermost manholes having constant flow; proportion the calculated dose between all points of application. Apply dose to all points as rapidly as possible, during or just before the peak flow. Where slime growths are heavy, flush sewers several days after the chemical dose.

31. Repairs

Repair work, found necessary during annual inspection or cleaning of sewers, must be scheduled to maintain an even work load. This work includes repairing manhole masonry and steps, changing grade of manhole covers, eliminating surface and roof-drain inlets, caulking joints, and replacing misaligned sewer sections. Sewer breaks, severe obstructions, and other damage causing sanitary hazards must be repaired at once.

a. ADEQUACY. Cause of trouble is determined if possible and repairs made to prevent recurrence of the difficulty. Thus, substantial bedding must be provided in replacing misaligned sewers, and backfill is carefully placed and tamped. Leaking joints are preferably recaulked with a bituminous joint compound. Sewers beneath roads or railroads

that are crushed by settling must be encased in concrete or replaced with cast-iron pipe unless the soil has become stabilized. In difficult situations, technical assistance of higher authority should be obtained.

b. Bypassing. Bypassing the sewage flow is usually required during repairs; the usual method is blocking the upper manhole outlet with sand bags or an expandable rubber plug, using portable pumps to discharge the sewage to the lower manhole through fire hose or a temporary pipe line.

c. Safety. Excavations must be braced and ladders provided in accordance with safety requirements for excavation, building, and construction. Adequate guards and warning signs are placed around excavations in roadways.

32. Extensions

a. Design. Sewer system extensions are designed in accordance with criteria of the OCE Engineering Manual. The following general principles apply to minor extensions:

(1) Sewer sizes must be large enough to carry peak flows from the areas they serve; future needs and extensions of the area must be considered. All building sewers cannot be smaller than 6 inches. Laterals, branches, and main lines cannot be less than 8 inches.

(2) The slope of sewer lines must provide a minimum velocity of 2 feet per second (fps) when flowing full or half full. Where higher grades require deep excavations, 1.5 fps is permitted. The following tabulation shows the slope required to maintain the desired velocity:

Diameter of sewer (inches)	Slope in feet per 1,000 feet	
	For velocity of 2 fps	For velocity of 1½ fps
6	6.0	3.6
8	4.0	2.3
10	2.9	1.6
12	2.2	1.2
15	1.5	.86
18	1.2	.67

Note: The use of larger-size pipe on flat grades does not increase velocity of flow. Increased pipe size decreases depth so velocity remains the same or less.

(3) In designing extensions, peak flows are usually assumed to be 3.7 times the average flow expected from the area.

(4) Manholes are located at each change in direction or slope and at the end of each lateral. The distance between manholes on branches, laterals, and most main lines, unless of large size, cannot be greater than 400 feet.

(5) All building connections to sewers less than 24 inches in diameter are made with commercially manufactured Y-branches or tees unless connection can be made directly to a manhole. Figure 21 shows proper methods of connection.

(6) Standard details of design, which may be modified to fit local conditions, are available from OCE.

b. Materials. Gravity sewer pipe of vitrified tile, concrete, cement-asbestos, or bituminous-impregnated fiber may be used. The latter two materials usually cost more but may be economical because of lighter shipping weight and ease of installation. For force mains and stream crossings, cast-iron or cement-asbestos pipe are used. Concrete pipe cannot be used for acid wastes or in localities where concrete-pipe deterioration has been experienced. For joint material on gravity lines, bituminous joint compounds (hot-poured, plastic, or preformed types) are preferable to cement mortar. A special joint compound is required for bituminous-impregnated fiber pipe.

c. Specifications. Standard OCE construction specifications are available on excavation, backfill, and sewer construction.

d. Laying pipe. Methods for setting line and grade, excavation, shoring, trench dewatering, laying of pipe, and backfill are contained in available texts. * Figure 22 shows a common method of laying sewer to line and grade. Construction methods must conform with OCE Safety Manual, Safety Requirements for Excavation, Building, and Construction.

33. Records

Maps of the sewer system are maintained in accordance with paragraph 22. Alterations and extensions to the system are added to the maps promptly. Maintenance records are maintained as prescribed in TM 5-666.

* Sewerage and Sewage Treatment, W. A. Hardenbergh; American Sewerage Practice, Vol. II, Metcalf and Eddy.

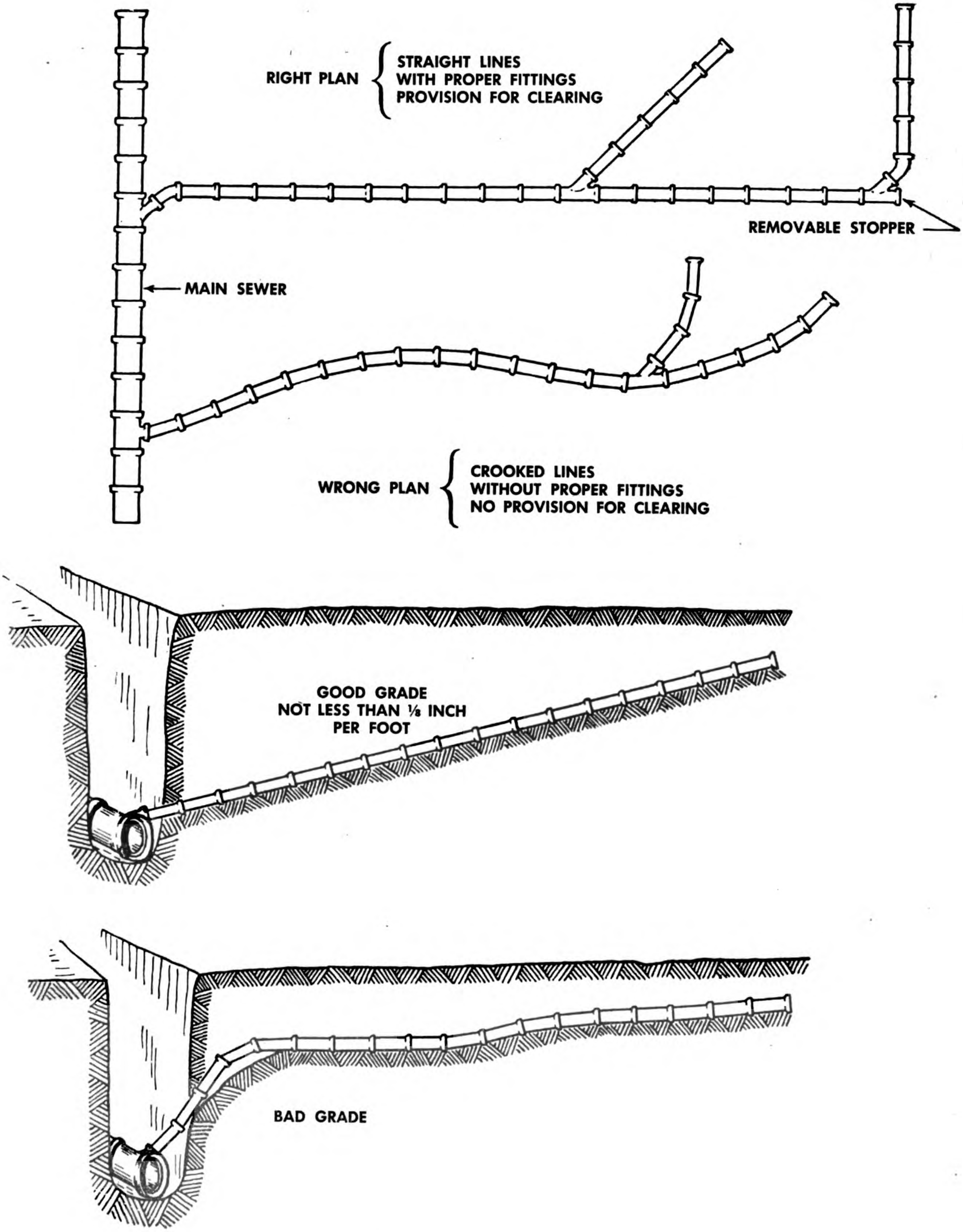


FIGURE 21. *Methods of laying sewer connections.*

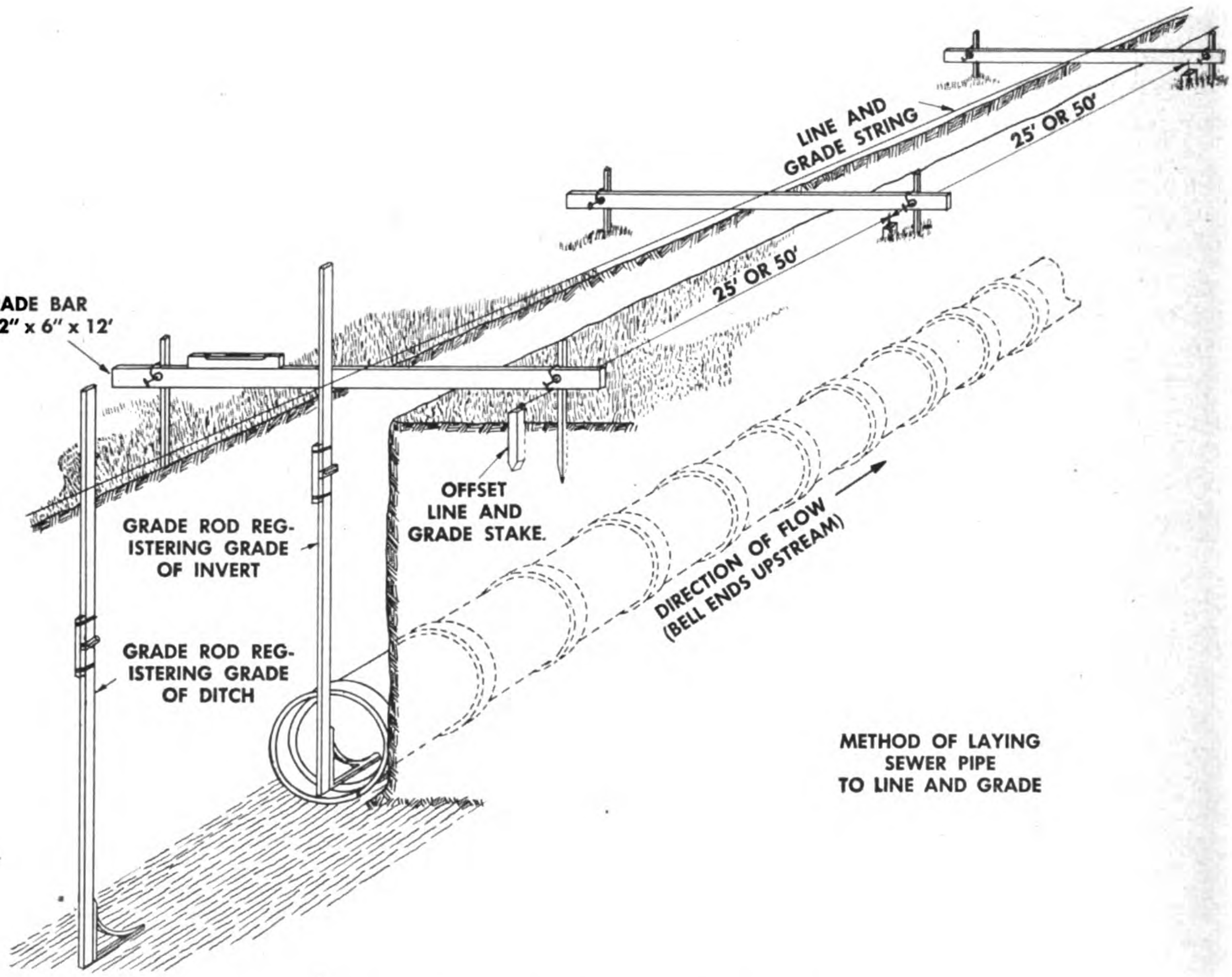


FIGURE 22. *Laying sewer pipe to line and grade.*

CHAPTER 3
SEWAGE PUMPS, LIFT STATIONS, AND FORCE MAINS

34. Types and Characteristics

Pumps for lifting sanitary sewage, storm water, and plant-unit effluents are usually high-capacity low-head types with large openings and low velocities to allow passage of large particles of solid material. The types in most common use are the centrifugal, axial-flow propeller, turbine, and ejector. A detailed description of pumps and their operation is given is TM 5–660 (when published).

a. Desirable characteristics in sewage pumps are freedom from clogging and resistance to wear. Most installations provide for pump protection by adequate screens or grinders which either remove the larger solids or cut them to a size which easily pass the pump openings. Because rags and strings which cause stoppage are most troublesome, provision is usually made in the pump casing for their ready removal.

b. Sewage pumps may be powered either by electric motors or internal-combustion engines. Gas from sewage digesters is sometimes used as a fuel.

35. Centrifugal Pumps

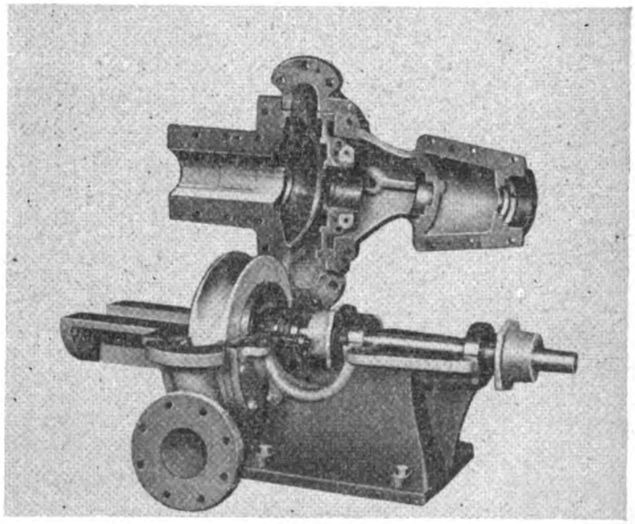
Centrifugal pumps are used to pump sanitary sewage because of their comparative simplicity, ease and efficiency of operation, and small dimensions. The type used for sewage is single-stage, slow-speed (about 1,150 rpm), mounted either horizontally or vertically. Figure 23 shows a typical single-stage horizontal type pump; figure 24 shows the vertical submerged type with float control.

a. STARTING OPERATION. The centrifugal pump must be filled completely with sewage before it is started to remove air from the casing and provide water for lubrication. If the pump is set above water level, priming devices are requ'red. The pumps are usually set either in the well from which the sewage is pumped or in a dry well outside and below the sewage elevation of the wet well. The suction lift must not be excessive, 15 feet being considered maximum; all piping on the suction side of the pump must be airtight to avoid air binding. If the pump characteristics differ from the requirements, the motor may overload and overheat. The manufacturer may be contacted concerning pump characteristics and recommendations for alterations.

b. FLUSH-KLEEN TYPE. Flush-kleen centrifugal pumps are widely used for sewage pumping to avoid some of the difficulties with clogging. (See fig. 25.) Sewage enters the discharge line of this type rather than discharging directly into the wet well; it passes through a strainer just ahead of the impeller where the solids are removed; sewage flows through the pump to the well. The pump lifts sewage from the well through the screen, forcing the retained solids into the discharge main. These pumps are installed in duplicate.

36. Axial-flow Pumps

Axial-flow propeller type pumps are described in TM 5–660 (when published). This high-capacity low-head pump is used largely for recirculating treatment-unit effluents and for pumping storm water.



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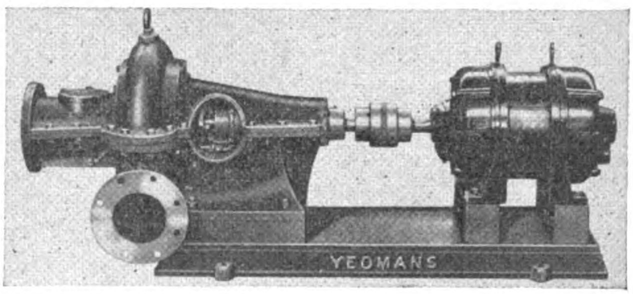

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FIGURE 23. *Horizontal type centrifugal pump for sewage.*

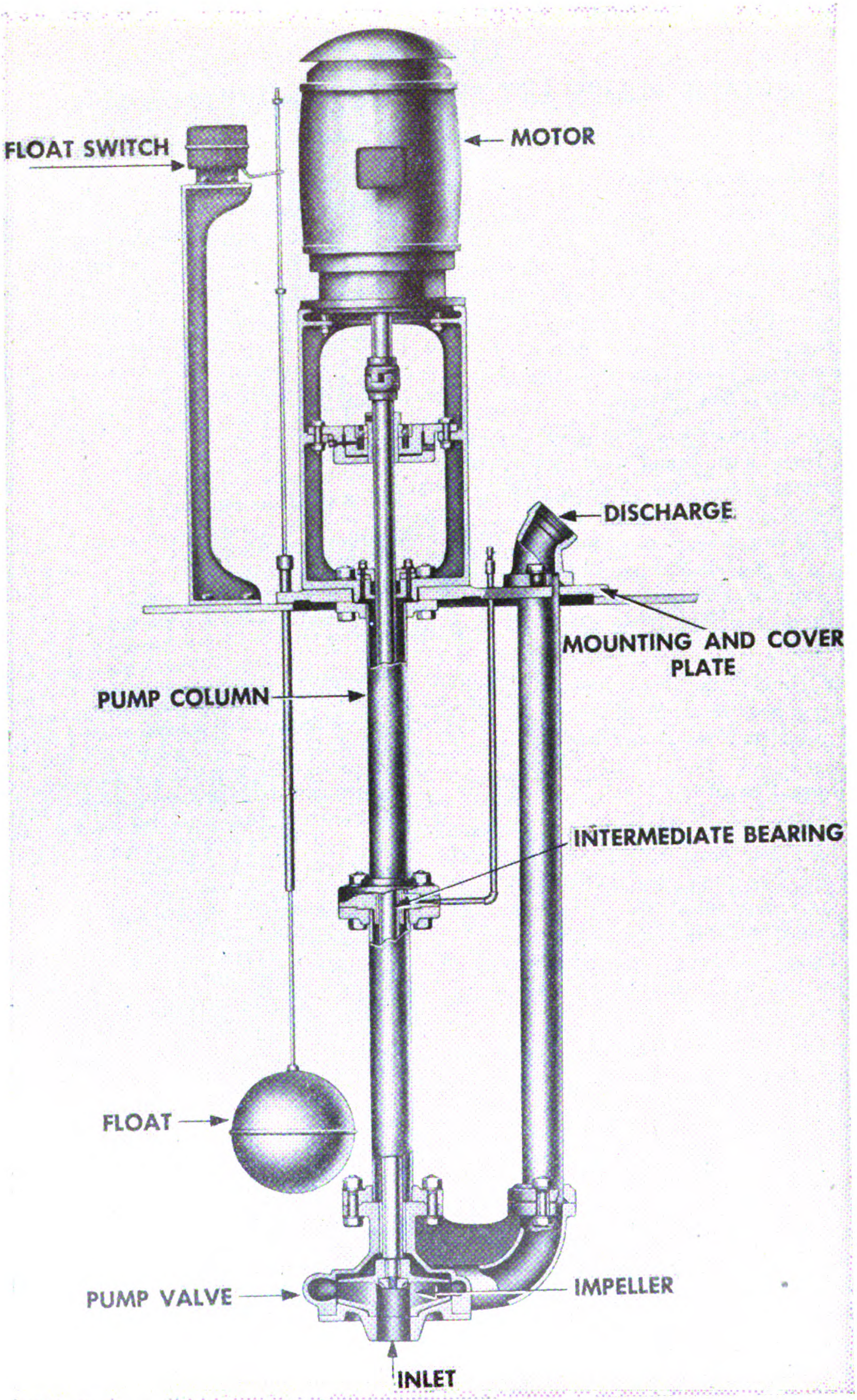


FIGURE 24. *Vertical submerged type centrifugal pump for sewage.*

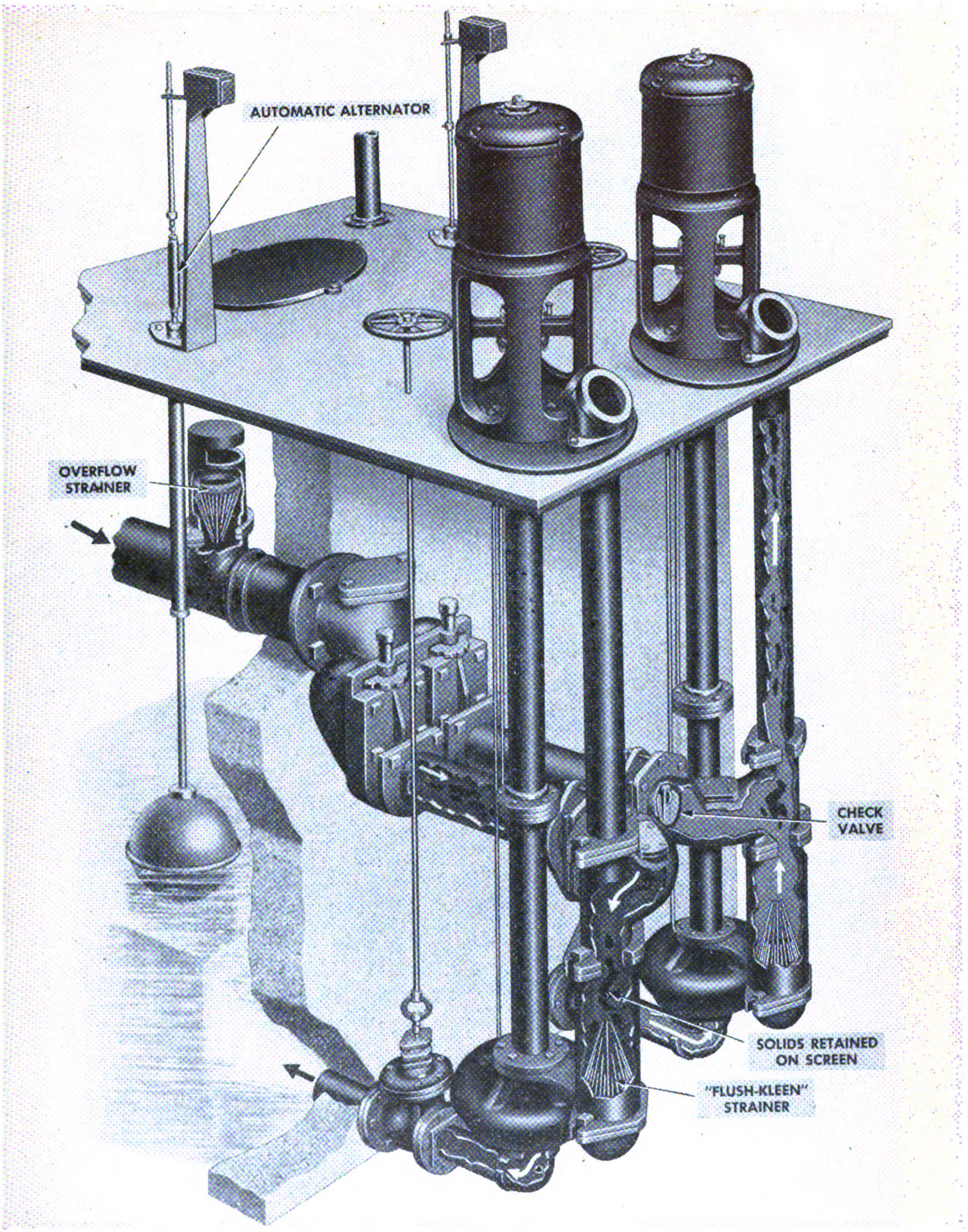


FIGURE 25. *Flush-kleen centrifugal pumps.*

37. Turbine Pumps

Turbine type pumps, also described in TM 5–660 (when published), are used to pump large volumes of storm water.

38. Sewage Ejectors

The sewage ejector is used to avoid the trouble of cleaning screens and clearing material from pumps. The sewage flows into a metal chamber; when the chamber is full, an automatic control admits compressed air which forces the sewage out through the discharge line. This installation requires air compressors, air tanks, and other items which make the first cost high. The efficiency is low, seldom attaining 15 percent. Sewage ejectors are better than centrifugal pumps for lifting sewage from basements of buildings into the main sewer because the relatively small flow requires a pump so small that it clogs easily. Figure 26 shows a typical installation lifting sewage from a manhole on a sewage line to a higher sewer. Figure 27 is a cross section of an ejector.

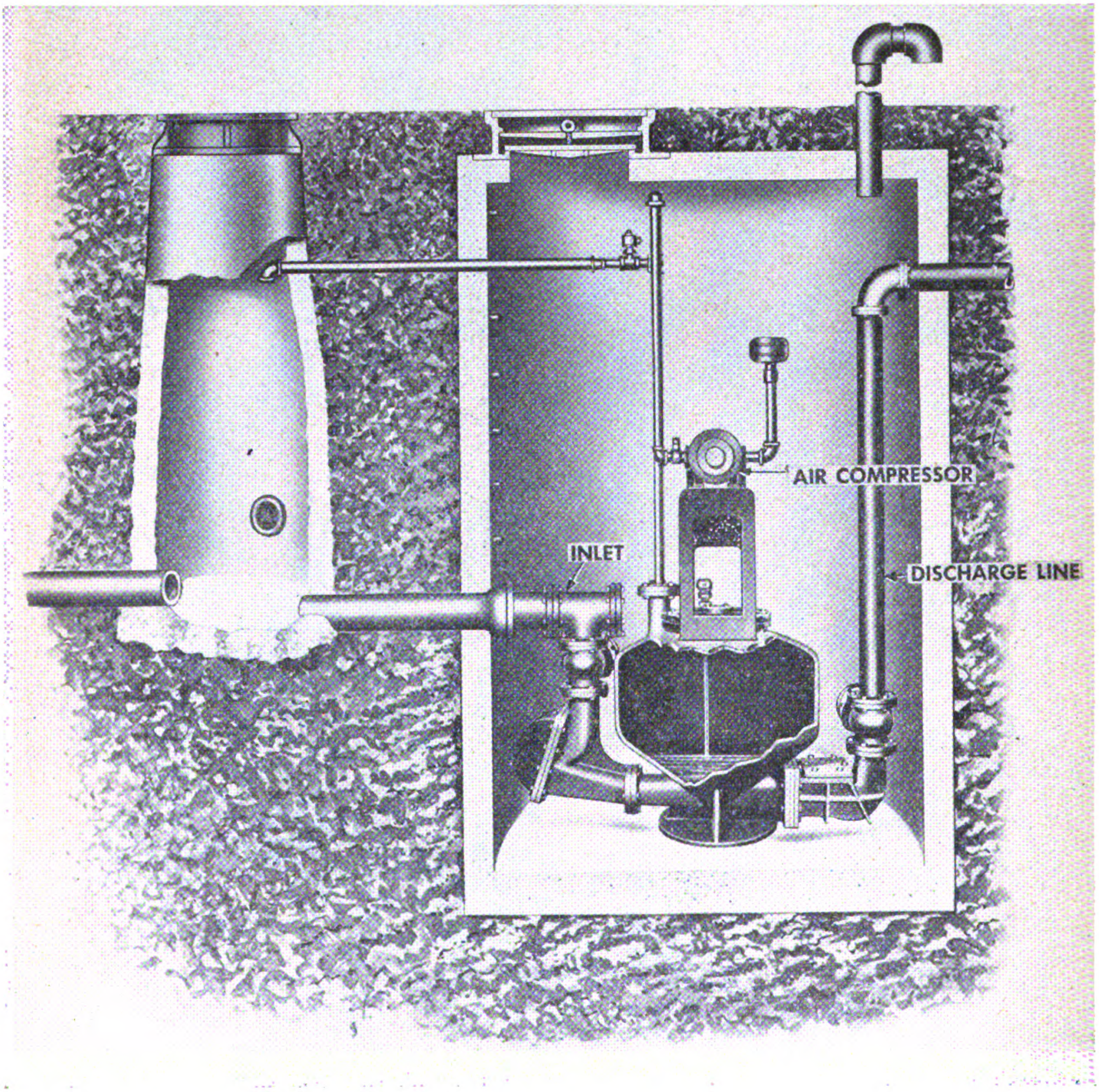


FIGURE 26. *Typical installation of sewage ejector.*

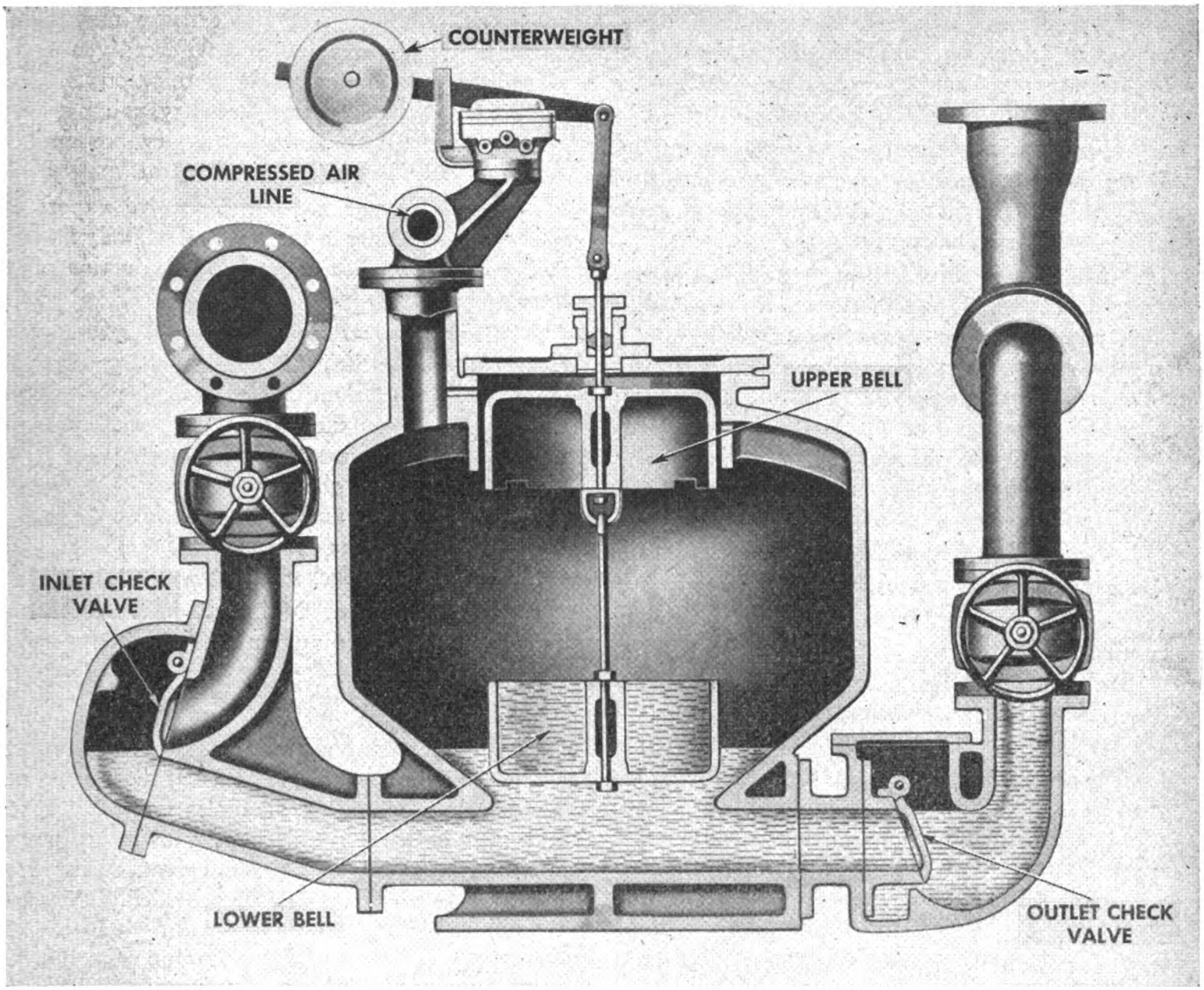


FIGURE 27. *Cross section of a sewage ejector.*

39. Controls

Pumping cycles controlled by float and sequence switches are adjusted if possible to avoid large fluctuations of flow to the treatment plant. Where pumps of different capacity are installed, the smaller pump is set to cut out when the larger pump starts, both pumps operating only at peak periods. Where two pumps of identical capacity are provided, their use is alternated frequently to provide equal wear. Standby pumps are operated manually once a week to dry out the windings and maintain proper operating condition. Since sewage pumps usually have automatic operation, the float control requires frequent attention. The float may be connected to the electric switch either by a push rod or a chain running over pulleys with a counterweight to balance the float. Floats hanging unprotected are likely to be moved sideways by the sewage, causing the rod to bend; some guiding device must be provided to prevent such damage. Proper protection must be provided to eliminate building up of ice on the rods exposed to the weather.

40. Operation of Pump Stations

Because pumping costs are often a major operating expense in a sewage treatment plant and sewage system, maintenance of normal efficiency of all pumping units is extremely important. Partly clogged pumps, worn impellers, and other inefficient conditions may increase greatly the power consumption and cost of repairs. In addition, break-downs may cause health hazards by backing up sewage in buildings or flooding low areas. Pumping stations are often located in housing areas where odors

caused by lack of cleanliness are especially objectionable. Continuous and efficient operation of pumping stations can be insured only by proper maintenance and frequent inspection.

a. WET WELL. Although most sewage pumping stations are equipped to operate automatically, daily attention is required. Accumulation of solids in the wet well must be prevented.

(1) The sewage level is drawn to minimum elevation daily; walls and bottom are thoroughly flushed with a heavy stream of water. This operation may require manual operation of pumps. Any air trapped in the pump can be bled by hand-following this operation if an automatic air-relief valve is not provided. If the potable water system is used for flushing, the hose must be removed from the well to prevent a cross connection.

(2) Grit accumulations are removed periodically by bucket and shovel if flushing is not effective.

(3) If slopes in the bottom of the wet well allow accumulations which are difficult to remove, they may be increased by laying concrete in the corners of the well sloping to the pump suction. Slopes of 1:2 or 1:1 are desired.

(4) Grease accumulation in float tubes is removed by daily flushing and scrapping with a home-made hoe-shaped tool whenever necessary. Replacement of float tubes with open guides of vertical-steel angle iron eliminates grease clogging.

b. SCREEENS. Bar screens and basket screens installed at pumping stations must be cleaned daily or more often if necessary to prevent obstruction to flow or overflow of basket. Methods of cleaning and disposal are given in paragraph 55.

c. DRY WELL. Water accumulations in the dry well are removed daily by the sump suction valve of a sewage pump. If a separate sump pump is available, this operation is done automatically by a float switch. The dry-well floor should slope toward the sump.

d. STRUCTURES. Structures housing pumping equipment require careful maintenance to prevent rapid deterioration.

(1) Pumping-station floors, walls, and windows must be kept clean to avoid odor nuisance and unsightliness.

(2) Acid-laden condensation from sewage, which severely corrodes concrete and masonry structures, steelwork, window sash, and settings may be relieved by adequate ventilation. Forced ventilation is necessary in underground installations without surface structures. Where necessary, paints specially manufactured to protect masonry are applied. All metal must be protected with paint.

e. GAS. Sewage gas and explosive vapors are likely to accumulate in the wet well. Daily flushing and removal of solids reduces the production of gas in the wet well.

f. CHECK-VALVE SLAM. In some cases, particularly where the lift is high and discharge pipes are long, check-valve slam occurs, which may fracture the pipe or loosen the joints. Remedial measures must be taken by installing the following:

(1) Slow-closing check valves.

(2) Large air chambers with small compressors to replenish air in the chamber.

(3) Hydraulic shock eliminators.

g. MAINTENANCE. Maintenance of pumps and auxialiary equipment is given in TM 5–666.

41. Force Mains

If force-main profiles show depressions and summits, air-relief valves should be installed at the high points. These valves are set in manholes for ready access and must be inspected frequently to insure proper operation. Protection of the valves during low-temperature periods should be provided.

42. Records

a. MONTHLY. Monthly operating logs include kilowatt hours (Kw-hr) used at remote pumping stations with that at the treatment plants if the remote station delivers sewage to a treatment plant. The quantity of screenings collected at pump stations, even remote from the treatment plant, are included with the report of the quantity collected at the plant.

b. DAILY. Daily logs for post-control purposes must show the following:

(1) Time of daily inspections, initialed by the operator.

(2) Daily power-meter readings.

(3) Kw-hr used per day.

(4) Operating pressures if pumps are equipped with gauges.

(5) Quantity of screenings removed in cubic feet.

CHAPTER 4
OPERATION OF TREATMENT PLANTS

Section I. CESSPOOLS, SEPTIC TANKS, AND SUBSURFACE DISPOSAL

43. General

Sewage treatment processes and plants described in this section include only those commonly used for small quantities of wastes and sewage; they are used largely at small posts or where common sewers are not available. The facilities are for the most part underground; if properly designed, constructed, and operated, they work without objectionable odors over long periods with a minimum of attention. The smallest unit considered is for a small group of people in a single building; the largest unit is suitable for about 500 persons where careful, continuous attendance to operation is not easily available. For sewage disposal within these limitations, cesspools, septic tanks, tile fields, and subsurface filters are commonly used. Intermittent sand filters are occasionally used for larger units where isolation is available and economical construction is important.

44. Cesspools

Sewage from small installations may be put in cesspools if a common sewerage system is not available. Cesspools are usually dry-laid masonry or brick-lined wells without any masonry at the bottom; the sewage flows into them and leaches out into the soil. Floating solids collect in the top and settling solids in the bottom of the well. The well's leaching capacity is exhausted when the solids accumulate and clog the soil. Use of chemicals is not recommended to increase the useful life of a cesspool.

a. Additions. When the first cesspool becomes filled, a second well may be constructed to take the overflow from the first. In such cases, the first should operate as a septic tank to collect the settling and floating solids and provide a trapped outlet on the connection leading to the next leaching cesspools. Septic tanks may be placed advantageously ahead of leaching cesspools in larger installations. Leaching cesspools should not be placed closer together than 20 feet by out-to-out measurement of walls.

b. Location. Leaching cesspools are used only where the subsoil is porous to a depth of at least 8 or 10 feet and where the ground-water table is normally below this elevation. Where located in fine sand, surrounding the walls with graded gravel has the effect of increasing the leaching area.

c. Size. Total number and size of cesspools required depends on quantity of sewage and leaching characteristics of the total exterior percolating area above the ground-water table, including bottoms and side walls below the maximum-flow lines. The allowable rate of sewage application per square foot per day based on the recommended leaching test is given below. Soils requiring more than 30 minutes for a fall of 1 inch are unsatisfactory for leaching, and some other disposal method should be used.

Time for water to fall 1 inch (minutes)	*Allowable rate of sewage application in gallons per square foot of percolating area per day*
1	5.3
2	4.3
5	3.2
10	2.3
30	1.1

d. Test. The test for leaching should be made by digging a pit about one-half the proposed depth of the cesspool with a test hole 1 foot square and 18 inches deep in the bottom. The test hole is filled with water to a depth of 6 inches which is allowed to drain off. Water 6 inches deep is again added, and the downward rate of percolation measured in minutes required for the water surface to lower 1 inch in the hole.

45. Septic Tanks

Septic tanks may be used to serve small or scattered installations where the effluent can be disposed of by dilution, leaching wells or trenches, subsurface tile, or artifical subsurface filter systems.

a. Capacity. Septic-tank capacity should equal a full day's flow plus an allowance of from 15 to 25 percent for sludge capacity. The minimum desirable size of tank is 500 gallons.

b. Design details. For emergency and temporary construction, septic tanks are made of wood or nonreinforced concrete with wood covers and baffles. Reinforced-concrete construction is more suitable for permanent installations. Standard plans are available from OCE on drawing 672–300.

The tank's length should be not less than two nor more than three times the width; liquid depth should be not less than 4 feet for the smaller tanks and 6 feet for the larger ones. Manholes should be provided over the inlet and outlet pipes and over the low points in the bottom of hopper-bottom tanks. The tank's roof may be covered with earth, but access openings should extend at least to the ground surface. Although ells or tees may be used at inlet and outlet connections, straight connections are better for rodding. Instead of ells, wooden baffles located approximately 18 inches from the ends of the tank and extending 18 inches below and 12 inches above the flow line are provided.

Elevations should provide free flow into and out of the tank. The bottom of the inlet sewer should be at least 3 inches above the water level in the tank. The inlet and outlet connections should be sufficiently buried or otherwise protected to prevent damage by traffic or frost.

c. Operation. Although properly designed septic tanks require little operating attention, they must be inspected periodically, frequency being determined by size of tank and population load. Minimum frequency should be once every 2 months at periods of high flow. The inspection must determine that inlet and outlet are free from clogging, that the depth of scum and sludge accumulation is not excessive, and that the effluent passing to subsurface disposal is relatively free from suspended solids. A high concentration of suspended solids in the effluent quickly clogs subsurface disposal facilities. Sludge and scum accumulation cannot exceed one-fourth of tank capacity. Statements sometimes made that septic tanks liquefy all solids, that they never need cleaning, and that the effluent is pure and free from germs are not true. Perhaps 40 to 60 percent of the suspended solids are retained, the rest being discharged in the effluent.

d. Sludge and scum disposal. Separating sludge and scum from the liquid in septic tanks is difficult; for small tanks they are customarily mixed, the entire contents being removed when cleaning. The material removed contains fresh or partially digested sewage solids which must be disposed of without endangering public health. Disposal through manholes in the nearest sewerage system as approved by local authorities or burial in shallow furrows on open land is recommended. A diaphragm type sludge pump is best suited for removing the tank contents which should be transported in a watertight closed container. Figure 28 shows a truck-mounted pump and tank assembled for this purpose.

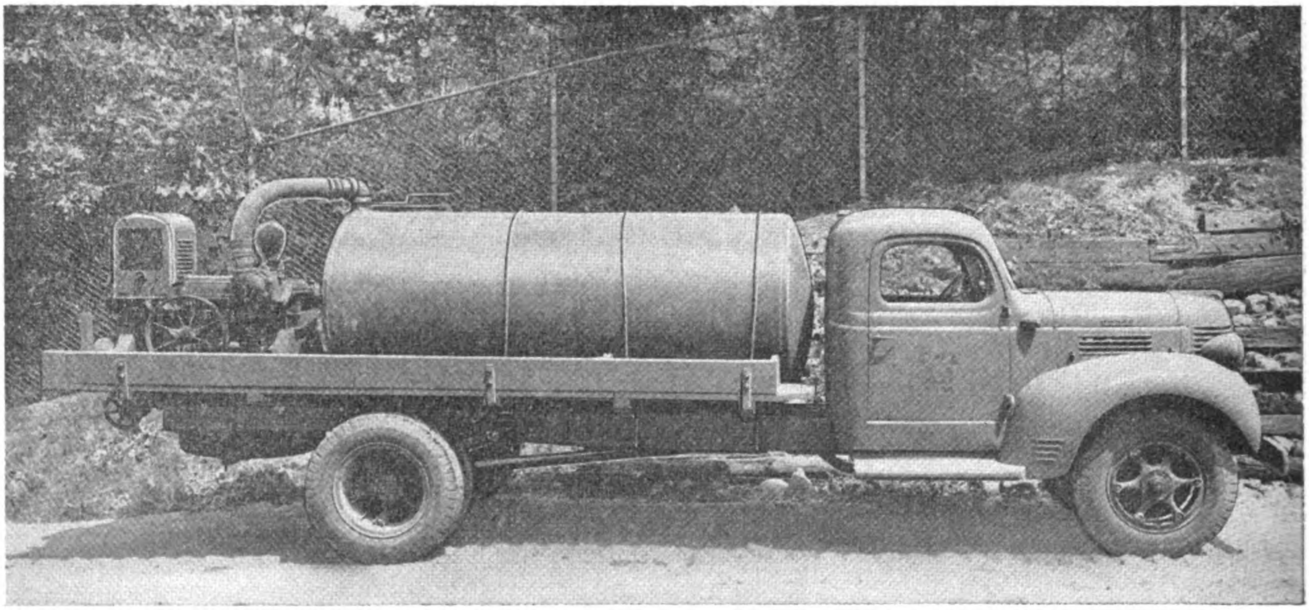


Figure 28. *Tank and diaphragm-pump assembly for cleaning septic tanks.*

46. Tile Fields

Tile fields of lines of cement or clay farm tile laid in the ground with open joints are used to dispose of settled sewage into the ground. A fiber pipe (Orangeburg Alkacid) with holes bored in the lower portion of the pipe to allow drainage may be used for these drain lines. This pipe is light, easily laid in the trench, and made in sizes between 2 and 8

inches in diameter and 5 and 8 feet in length. Because of these long lengths, it is particularly valuable in soil where other types may settle unevenly. Figure 29 shows a typical field lay-out.

a. Proper functioning. The following conditions are important for proper functioning of tile fields:

(1) Ground water well below the level of the tile field.

(2) Soil of satisfactory leaching characteristics within a few feet of the surface, extending several feet below the tile.

(3) Subsurface drainage away from the field.

(4) Adequate area.

(5) Freedom from possibility of polluting drinking-water supplies, particularly from shallow dug or driven wells in the vicinity.

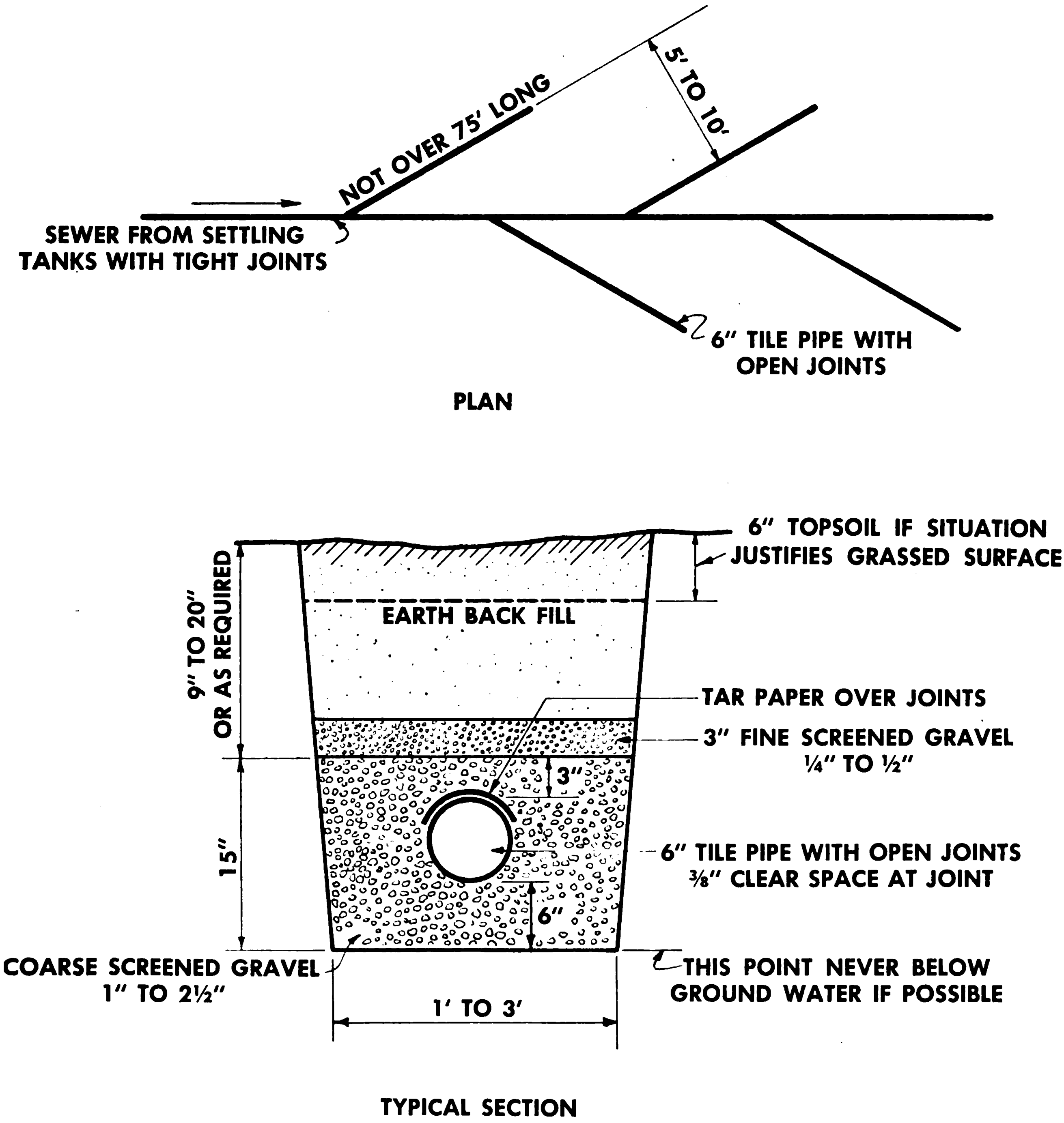


Figure 29. *Typical lay-out of a subsurface tile system.*

b. TESTS. Length of tile and details of the filter trench generally depend upon the character of the soil. Soil-leaching tests should be made at the site as described for leaching cesspools (par. 44), except that the test hole should extend only to the approximate depth at which the tile lines are to be laid. For extensive tile fields, several tests to determine the best location and average conditions should be made. From test results, the rate of sewage application to the total bottom area of the tiled trenches may be taken from the table below. Soil testing over 30 minutes is not suitable.

Time for water to fall 1 inch (minutes)	*Allowable rate of sewage application in gallons per square foot per day, bottom of trench in tile field*
1	4.0
2	3.2
5	2.4
10	1.7
30	.8

c. TRENCH WIDTH. Minimum widths of trenches on the basis of soils are as follows:

(1) Sand and sandy loam, 1 foot.

(2) Loam and sand and clay mixture, 2 feet.

(3) Clay with some gravel, 3 feet.

d. FROST LINE. Placing tile below the frost line to prevent freezing is not necessary. Tile placed 18 inches below the ground surface operated successfully in New England for many years. Subsurface tile should never be laid below ground-water level.

e. PIPE SIZE. Design and construction should provide for handling and storage of some solid material, eliminating as much as practicable the opportunity for clogging near pipe joints. Pipe 3 to 6 inches in diameter is recommended. The larger pipe gives greater storage capacity for solids and a larger area at the joint for solids to escape into the surrounding gravel.

f. LAYING THE PIPE. To provide for free discharge of solids from the line to the filter trench, the pipe must be laid with 3/8-inch-clear openings. The top of the space is covered with tarpaper or similar material to prevent entry of gravel. Bell and spigot pipe is easily laid to true line and grade. Good practice calls for breaking away two-thirds along the bottom of the bells at the joint and using small wood-block spacers. The pipe is commonly laid at a slope of about 0.5 foot per 100 feet when taking the discharge directly from the septic tank and 0.3 foot per 100 feet when a dosing tank is used ahead of the field.

g. BEDS. The tile is laid on a bed of screened coarse gravel 6 inches deep with 3 inches of coarse gravel around and over the pipe. Coarse screened stone passing a 2½-inch mesh and retained on a ¾-inch mesh is recommended. This gravel bed gives a relatively large percentage of voids into which the solids may pass and collect before the effective leaching area becomes seriously clogged. The soil which fills the trench must not fill the voids in the coarse screened gravel around the pipe. A 3-inch layer of medium screened gravel over the coarse stone and 3 inches of either fine screened gravel or suitable bank-run gravel over the medium stone is recommended.

h. LAY-OUT. The lay-out of the tile in the field should be carefully designed. Generally, the length of laterals should not be greater than 75 feet. When tile is laid in sloping ground, the flow must be distributed so each lateral gets a fair portion. Flow must be prevented from discharging down the slope to the lowest point. Individual lines should be laid nearly parallel to land contours. (See fig. 30.) Tile fields are commonly laid out either in a herringbone pattern or with the laterals at right angles to the main distributor. Distance between laterals is 3 times the width of the trench. Distribution boxes to which the laterals are connected may be desirable. Trenches 24 inches wide or more are economical. If a trenching machine is practical on a large installation, the design should be based on the width of trench excavated by the machine.

i. PROTECTING THE FIELD. Once a tile fiield is constructed, all traffic must be excluded by fencing or posting to prevent crushing the tile. Planting shrubs or trees over the field is not good practice since the roots tend to clog the tile lines; grass over the lines assists in removing the moisture and keeping the soil open. A typical section of a tile filter trench is shown in figure 29.

47. Subsurface Filters

Where the soil is so dense and impervious that a subsurface tile-trench system is impractical and where lack of an isolated area prevents use of an open filter, subsurface filter trenches or beds may be required. Underdrains from subsurface filter trenches or beds may be discharged freely to the nearest satisfactory point of disposal such as a small stream, dry stream bed, or on land.

a. DESIGN. The filter trenches or beds should be designed for a rate of filteration not greater than 1 gallon per square foot per day. The filtering ma-

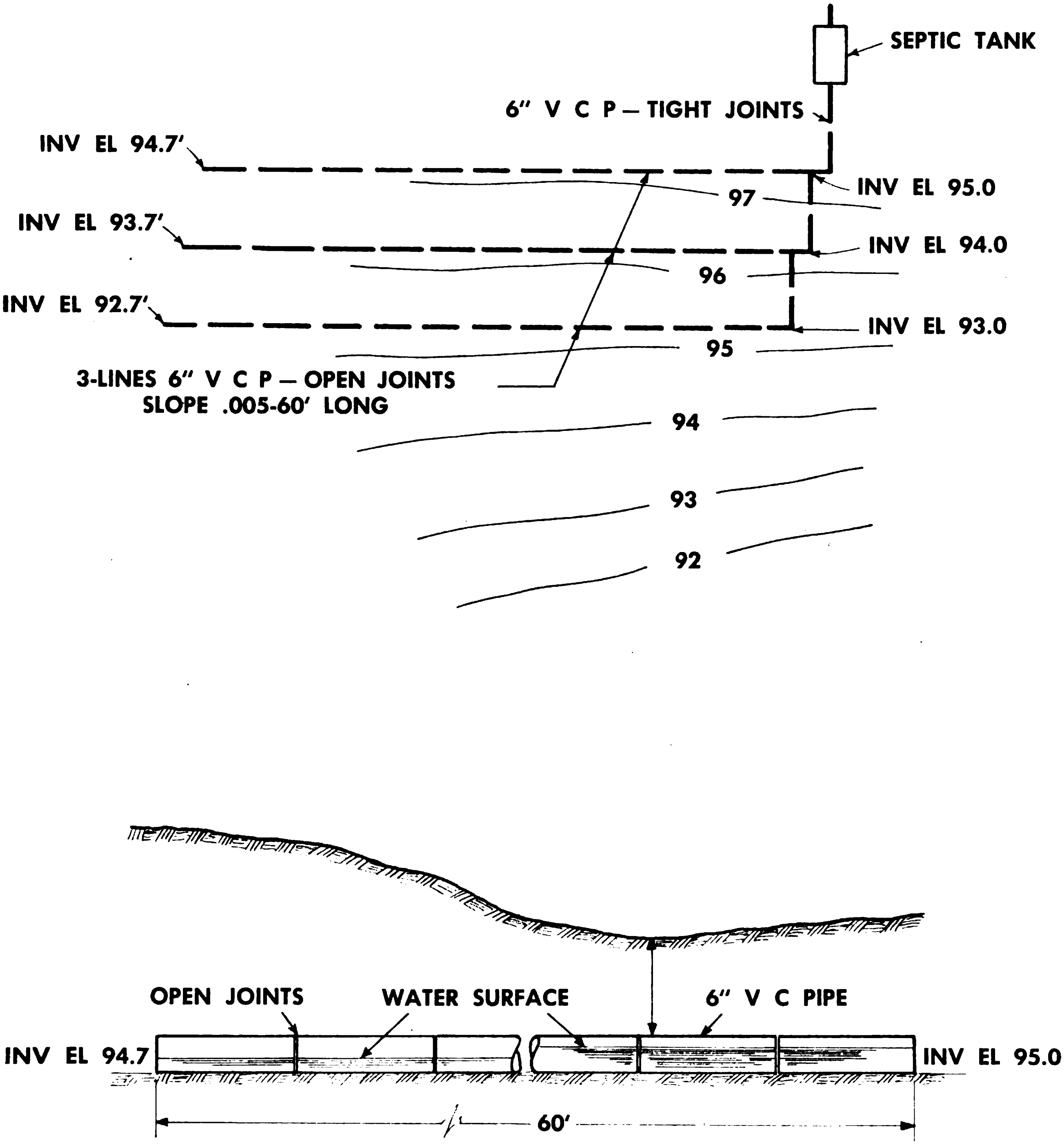


FIGURE 30. *Typical lay-out of tile field on sloping ground.*

terial should be clean, coarse sand all passing a ¼-inch mesh with an effective size between 0.25 and 0.5 millimeters and a uniformity coefficient not greater than 4.0. Filtering sand should generally be not less than 30 inches deep. Coarse screened gravel should pass a 2½-inch mesh and be retained on a ¾-inch mesh. A typical section of an underdrained filter trench is shown in figure 31. Governing conditions for the field lay-out are similar to those for the tile fields described above.

b. LAY-OUT. A typical plan and section for a subsurface filter bed are shown in figure 32. Slope of the distributors should be about 0.3 foot per 100 feet when a dosing tank is used or 0.5 foot per 100 feet when no dosing tank is required. For installations having more than 800 feet of distributors,

the filter should be built in two or more sections with alterating siphons to alternate the flow between sections. The trenches should be 2½ to 4 feet wide; tile lines in beds should be laid on 5- to 10-foot centers.

48. Dosing Tanks

Dosing tanks with automatic sewage siphons should be provided for tile or subsurface fields when the length of distribution tile exceeds 300 feet. Dosing tanks should be designed to discharge a volume equal to 70 to 80 percent of the volumetric capacity of the distribution piping in the tile field or filter. The dosing tank can usually be constructed in the same width and as a part of the septic tank. (See fig. 33.) The high-water level should be not less than 3 inches below the level of the sewage in the septic tank. Manufacturers' bulletins for standard capacities and details of sewage siphons should be consulted.

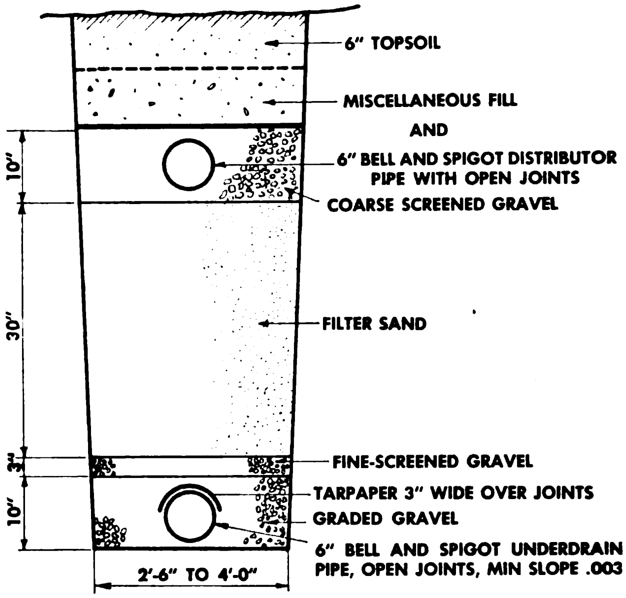


FIGURE 31. *Typical section of underdrained filter trench.*

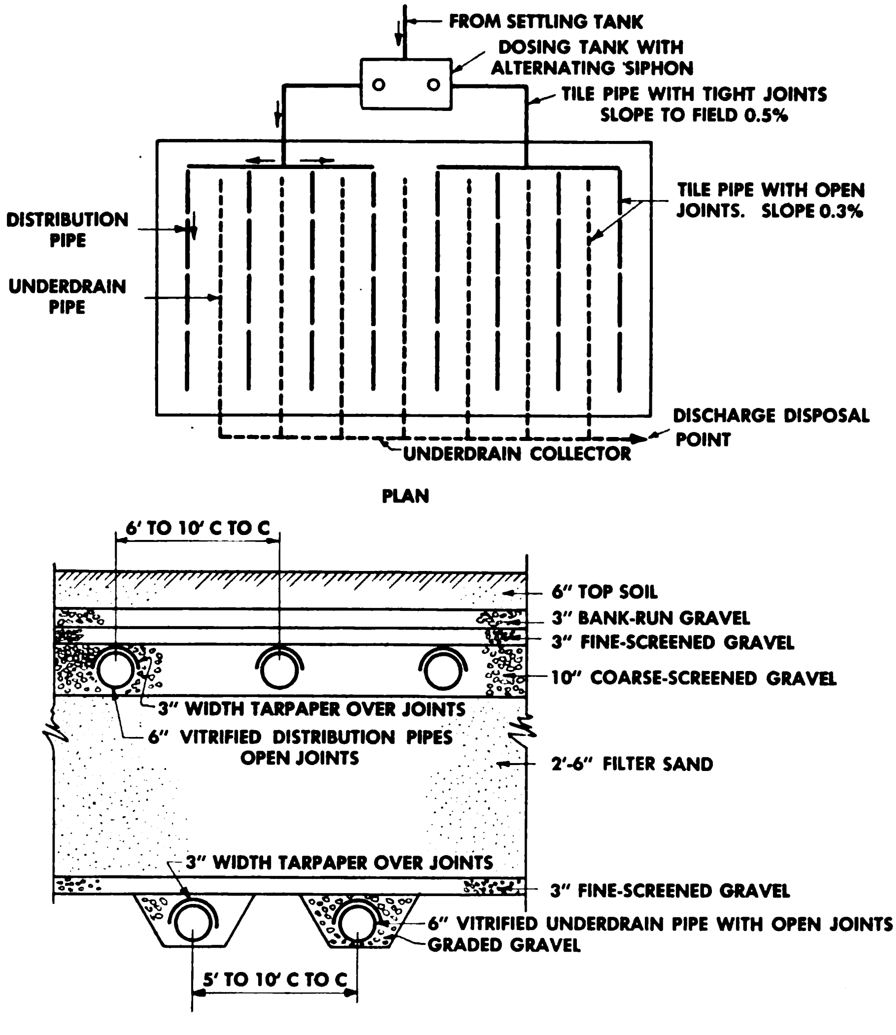


FIGURE 32. *Typical plan and section of subsurface sand filter.*

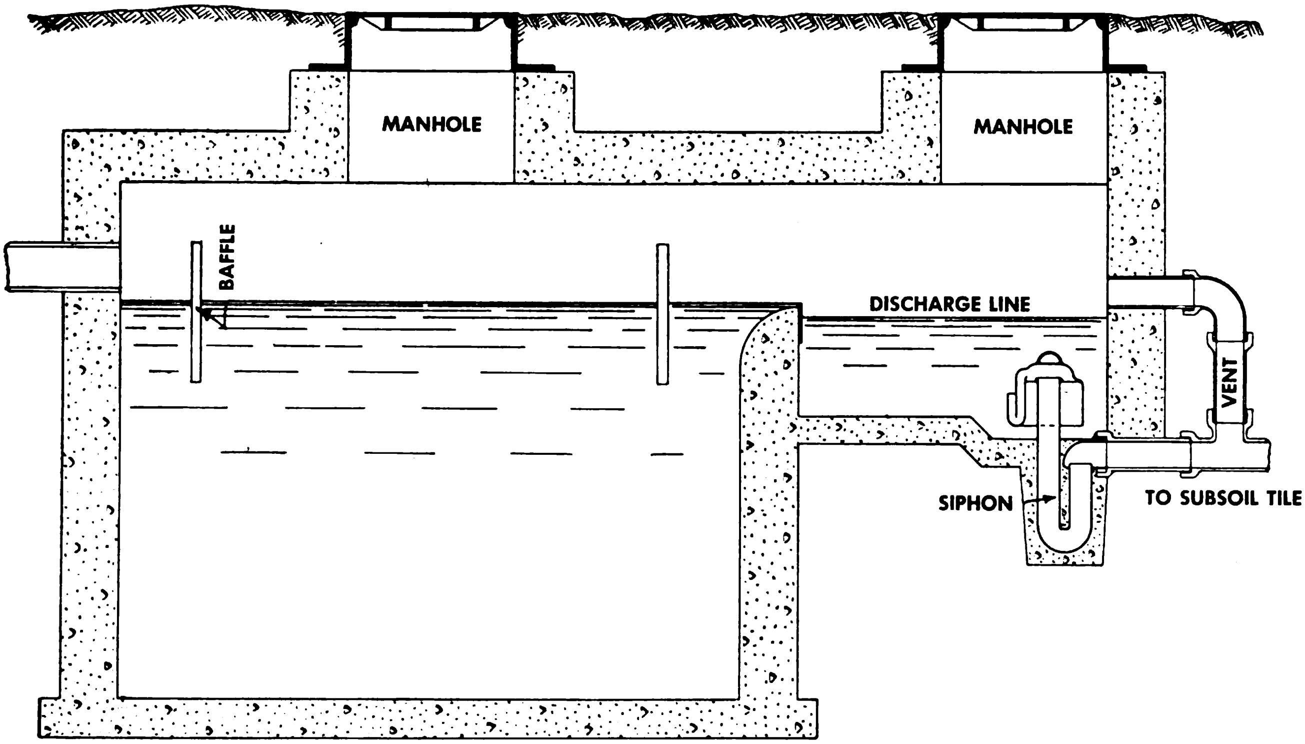


FIGURE 33. *Septic tank with dosing siphon.*

49. Treatment of Kitchen Wastes

If kitchen wastes from grease traps bypass the septic tank provided for the sewage, the grease and solids soon clog the tile field. Kitchen wastes, after passing through the grease trap, must be treated in a septic or other settling tank before discharge into the title field; they may be treated in the same tank provided for other sewage flows. Action in the septic tank is not harmed by kitchen wastes.

Section II. GRIT CHAMBERS

50. Purpose

Grit chambers are used primarily to remove coarse, suspended inorganic matter from sewage. A grit chamber is an enlarged channel or long tank placed at the influent end of the treatment plant which it protects. The cross section of the chamber is designed to retard flow velocity just enough to cause the heavier solids to deposit, permitting removal of such heavy mineral matter as sand, gravel, cinders, and such heavy, nearly inert, organic matter as coffee grounds, fruit seeds, and similar substances. This operation protects and permits proper operation of following treatment units. If this material is not removed, troublesome deposits occur in channels, piping, tanks, and other parts of the treatment plant where removal is laborious and expensive. Grit causes excessive wear of pumps, sludge collectors, and other equipment. Large quantities of grit are usually carried in combined sewer systems; the volume is usually small in separate systems except during excessive flows which remove deposits from sewers, or when breaks occur in the sewer system.

a. REMOVING ORGANIC MATTER. Grit, except very fine material, settles quickly when the velocity is reduced to about 1 foot per second. At slower velocity, some organic matter settles. This mixture of sand and decomposing organic matter may cause an odor nuisance in the grit chambers. Continuous-removal equipment is available for washing organic matter from grit and removing it from the grit chamber. This equipment collects the deposit at the foot of an incline, moving it up by scrapers or a screw type conveyor. This agitation causes the organic matter to be suspended again while the sand is retained on the scraper. Figure 34 shows a conveyor type grit-removal mechanism. Figure 35 shows a detritor mechanism which revolves about a center shaft.

b. REGULATING FLOW. Grit channels usually have proportional weirs, Parshall flumes, or other devices for automatically maintaining the proper velocity. In the absence of such devices, regulation is accomplished by stop gates periodically adjusted for proper velocity of 1 foot per second over the

normal daily flow variation. If more than 15 percent of the drained grit is organic material, the chamber is 'mproperly designed or operated. Figure 36 shows a proportional weir.

51. Operation

a. Manual removal. Usually two or more channels used alternately are provided for manually-cleaned chambers to allow draining and grit removal. Channels are designed to provide a lower compartment for the accumulated grit and an upper for the flowing sewage. The two compartments have no physical separation. Grit depth may be gauged by a graduated pole. Grit should be removed whenever 50 to 60 percent of the lower compartment is filled and immediately after every heavy storm. The following method of cleaning may be modified to suit the local conditions.

(1) Close the end gates to the channel to be cleaned and open the other channel.

(2) Drain by gravity or a portable pump if no drain is provided. Water is discharged to primary settling tanks.

(3) While draining, agitate and flush the material with water to remove organic solids and move sand to end of the channel opposite the drain.

(4) When the grit is drained, remove it with shovels and buckets.

b. Mechanical removal. Mechanical grit-removal equipment is usually operated intermittently except at larger plants where operation is frequent enough to prevent overloading and should be continuous during excessive flows. Grit from this type of equipment is relatively free of objectionable matter and can be used for covering screenings or filling poorly dra'ned areas. Where organic matter is present, burial or incineration is necessary.

c. Maintenance. Maintenance of grit-chamber mechanical equipment is given in TM 5–666.

52. Records

a. Monthly. The monthly operating log shows the following:

(1) Total cubic feet of grit removed for the month.

(2) Calculated cubic feet of grit per million gallons.

(3) Method of disposal.

b. Daily. The daily log shows the following:

(1) Date of cleaning.

(2) Volume of grit removed in cubic feet.

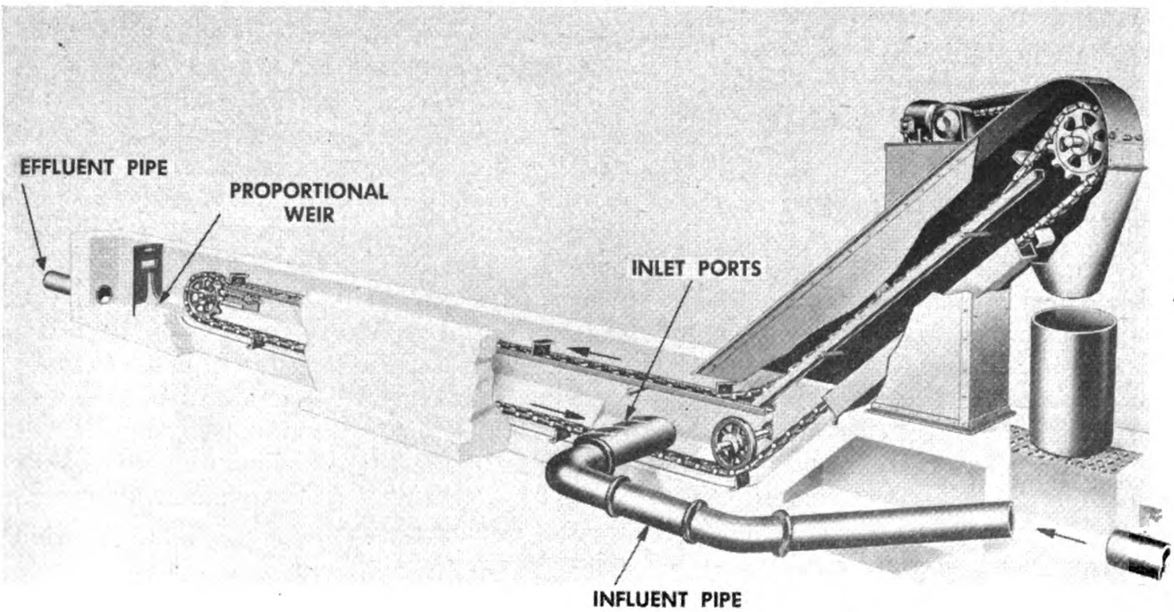


Figure 34. *Grit chamber with conveyor type grit-removal mechanism.*

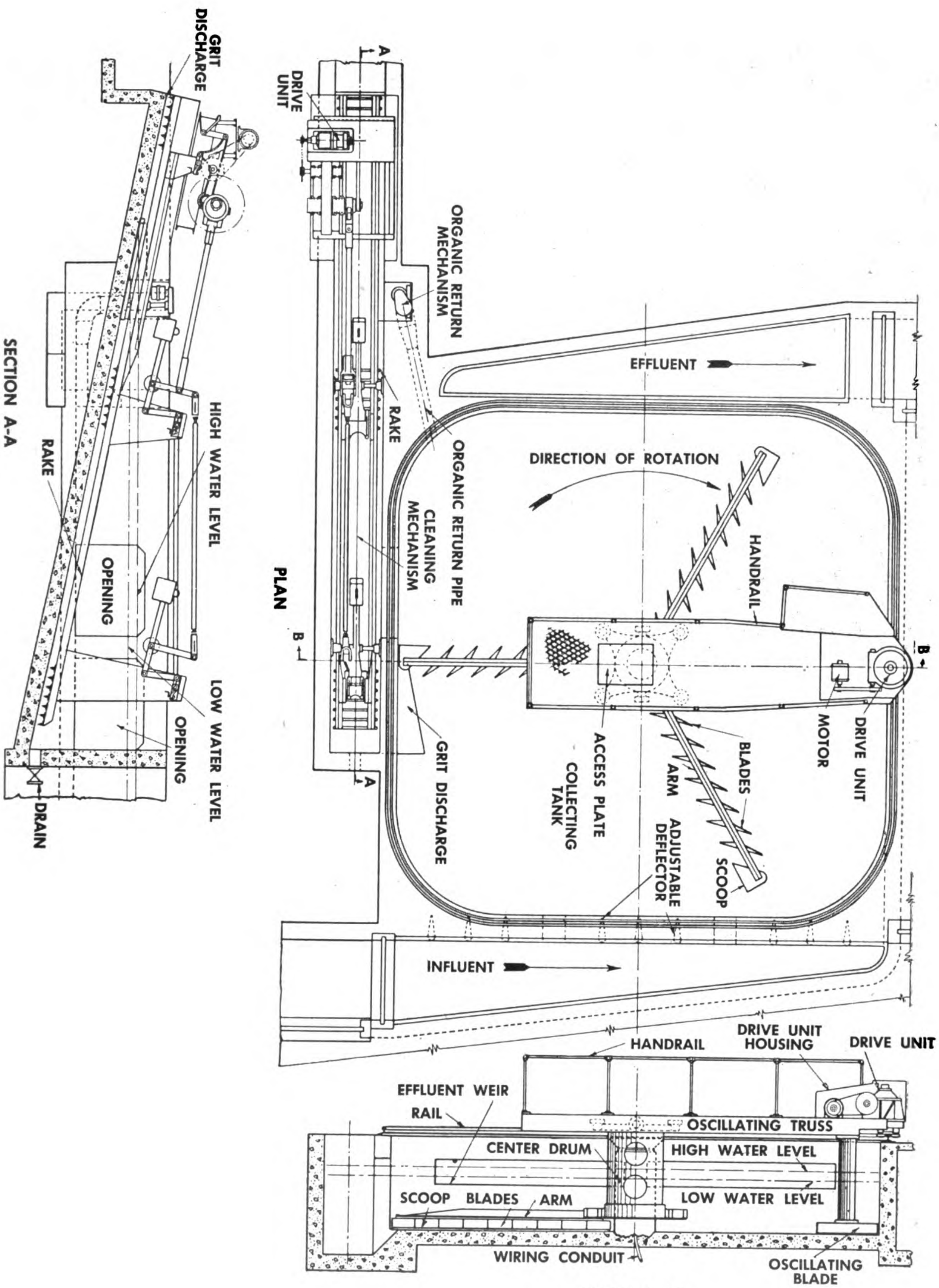


FIGURE 35. *Dorr detritor for grit removal.*

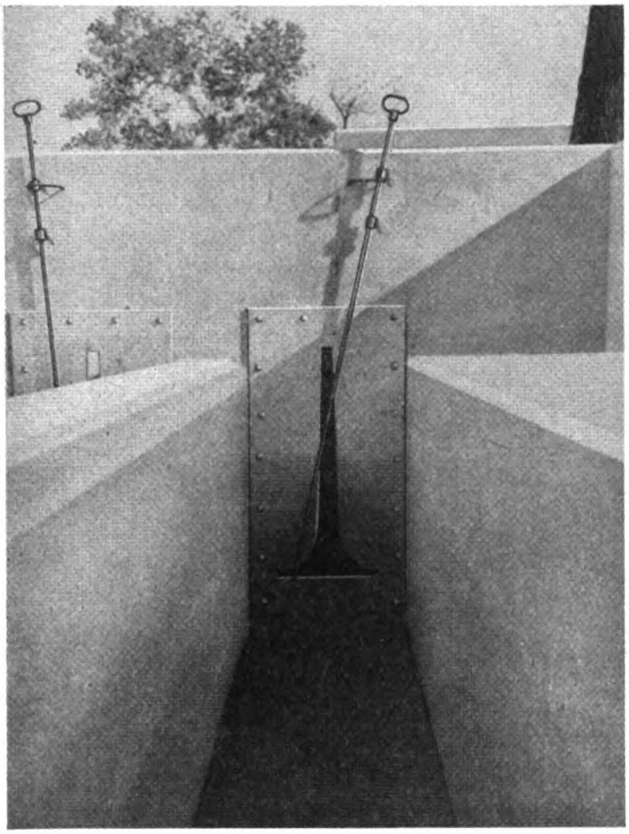


FIGURE 36. *Proportional weir.*

Section III. SCREENS AND GRINDERS

53. Types and Uses

Sewage plants and pumping stations are equipped with bar screens, comminutors, or other types of grinders whose function is elimination of large objects such as rags and wood which may clog pumps, piping, or other mechanical equipment. In some cases, fine screens of ¼-inch openings or less are used to remove additional suspended solids.

a. BAR SCREENS. Bar screens have a grid of steel bars spaced on centers varying from ¾ to 2½ inches and installed at an angle in the direction of the flow in an enlarged portion of the influent channel. (See fig. 37.) These screens may be cleaned manually with a rake by pulling the screenings up the bar and depositing them on a draining platform. Mechanical equipment, sometimes used to clean the screens (fig. 38), is operated intermittently by a time clock or a float switch actuated by increased head loss through the screen. This change in head loss is caused by the accumulation of screenings on the bars. The screenings are raked upward by the mechanism and dropped into a receptacle, grinder, or shredder.

b. GRINDERS. Some mechanical grinders use swing hammers to grind the solids into a pulp while rocks, iron, and other hard material are deposited to a trap. Others use a high-speed rotor fitted with tool-steel teeth which shred the material as it passes between them. The ground material is washed back into the raw sewage at a point beyond the screen.

c. COMMINUTORS. The comminutor has a vertical drum revolved by an electric motor. Cutting knives located on the drum shred solids too large to pass through openings between the knives. Sewage flows through these openings forcing the solids against the knives again and again until they are cut to proper size. The comminutor is installed in the inlet channel to the plant or pump station and usually used in conjunction with a bar screen. The latter is available for use when the comminutor is being repaired. Figure 39 shows a comminutor and a manually-cleaned bar screen. Figure 40 is a sectional drawing of a comminutor in place.

54. Operation

The bar screen must be kept clear by raking at frequent intervals. Neglect of cleaning may cause sewage to back up in the influent pipe and overflow the screen chamber. Clogged bar screens cause material to settle in the influent line where it becomes septic and odorous. This septic material is suddenly washed to the plant when the screen is cleared. This is objectionable since best plant performance is secured when the sewage is received fresh and in uniform amounts.

a. Rake screenings onto the drainage platform. As soon as most of the water has drained, place screenings in some covered receptable such as a 10-gallon garbage can with small holes in the bottom to drain off excess water. Place cover on can immediately and clean platform with water from a hose. Treat screenings from mechanical rakes similarly.

b. Flush screen chamber and screen at least once during each shift to remove grease from walls and bars and accumulated solids from the area ahead of the screen.

c. Clean fine screens by scrubbing or brushing, preferably with water under pressure from a hose. Remove grease on tools, screens, or other equipment with kerosene.

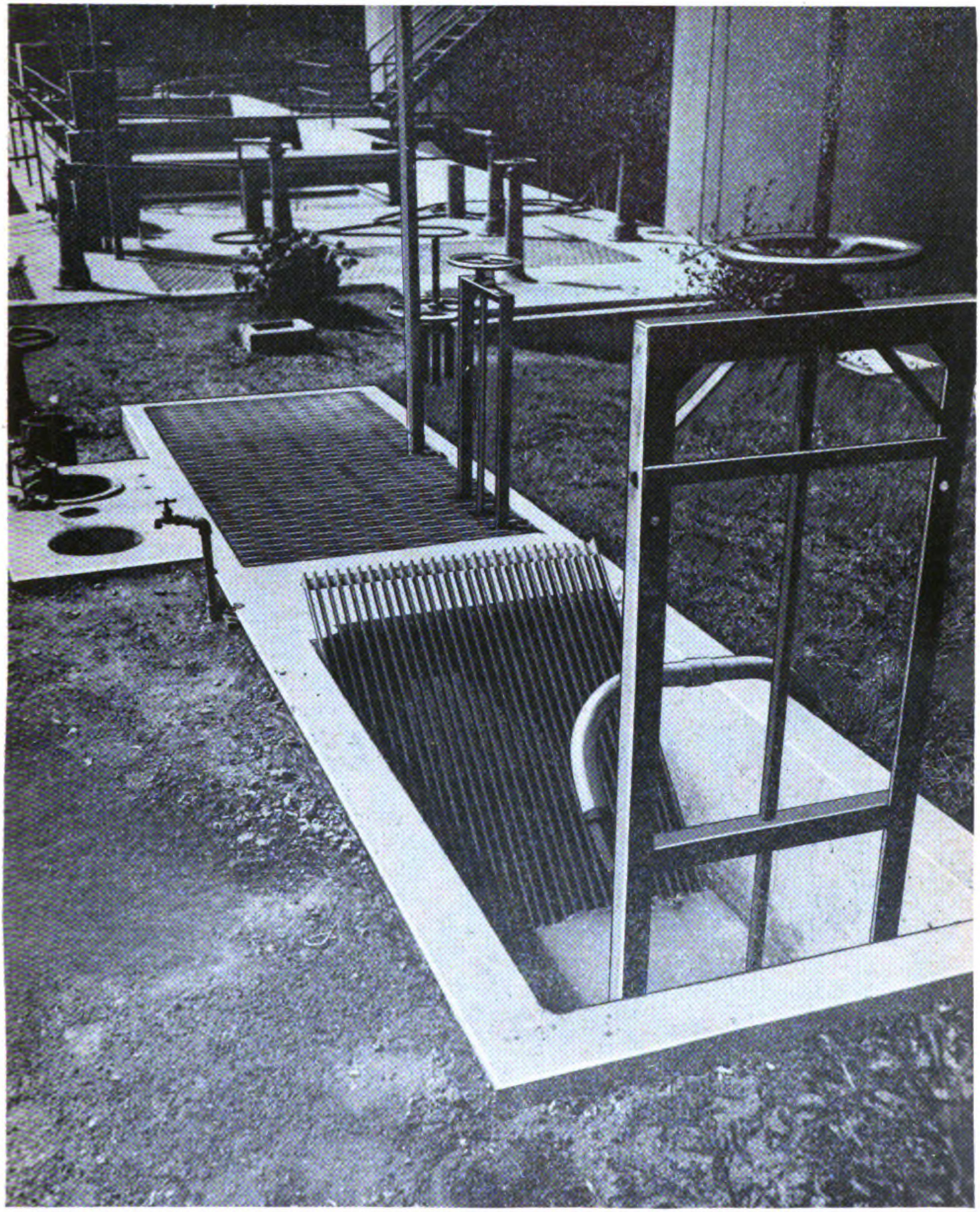


FIGURE 37. *Manually-cleaned bar screen.*

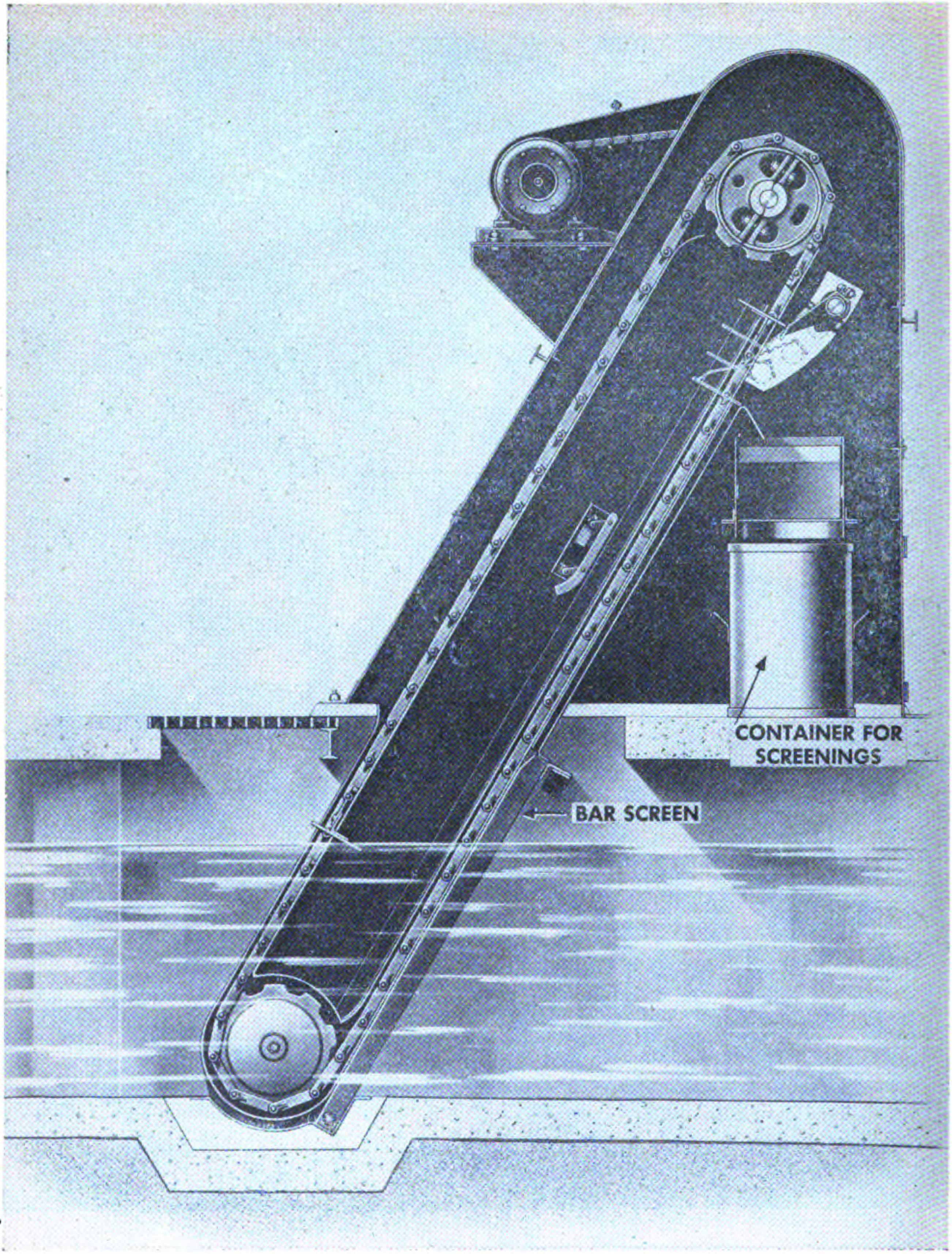


FIGURE 38. *Mechanically-cleaned bar screen.*

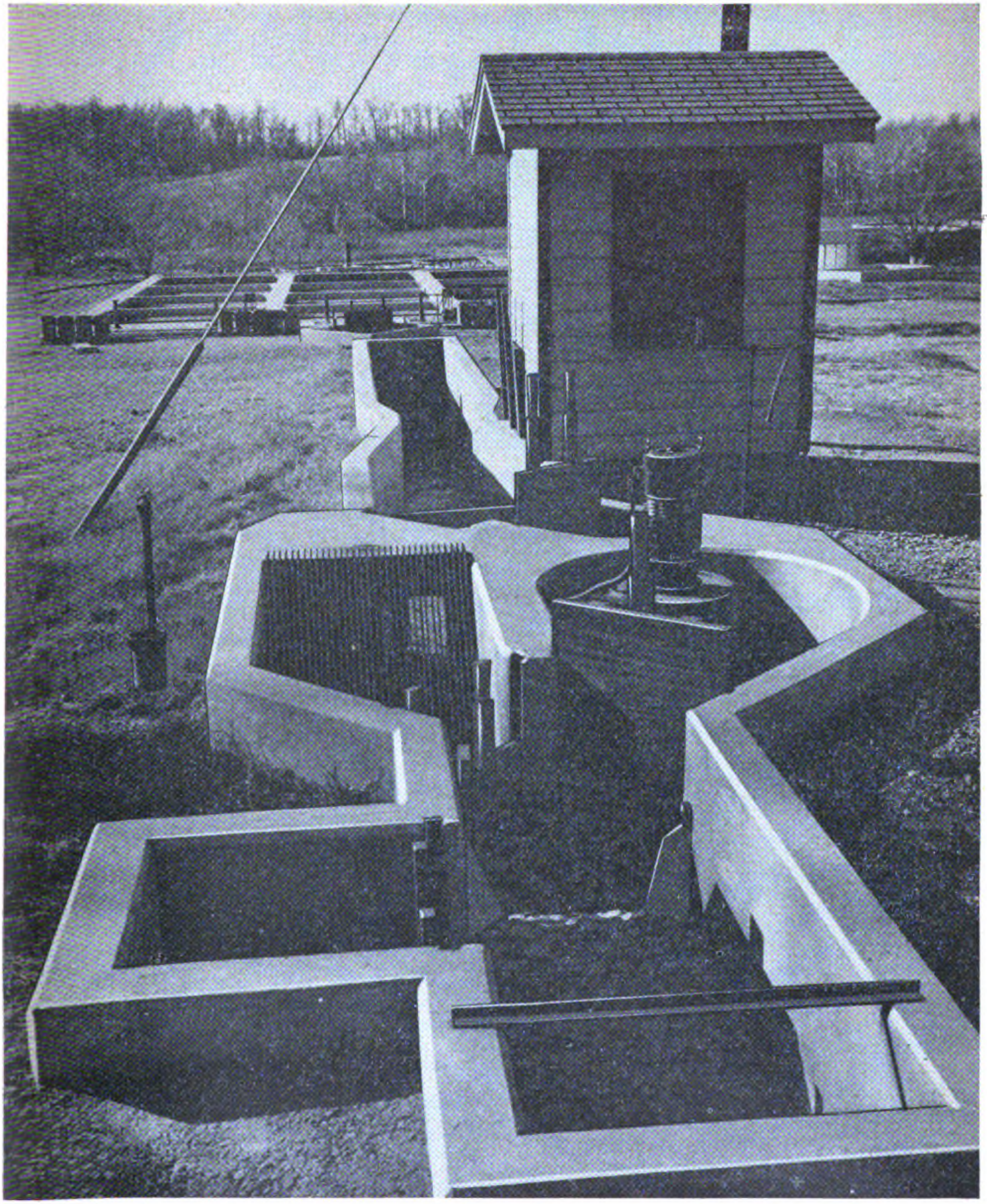


FIGURE 39. *Installation of comminutor and bar screen.*

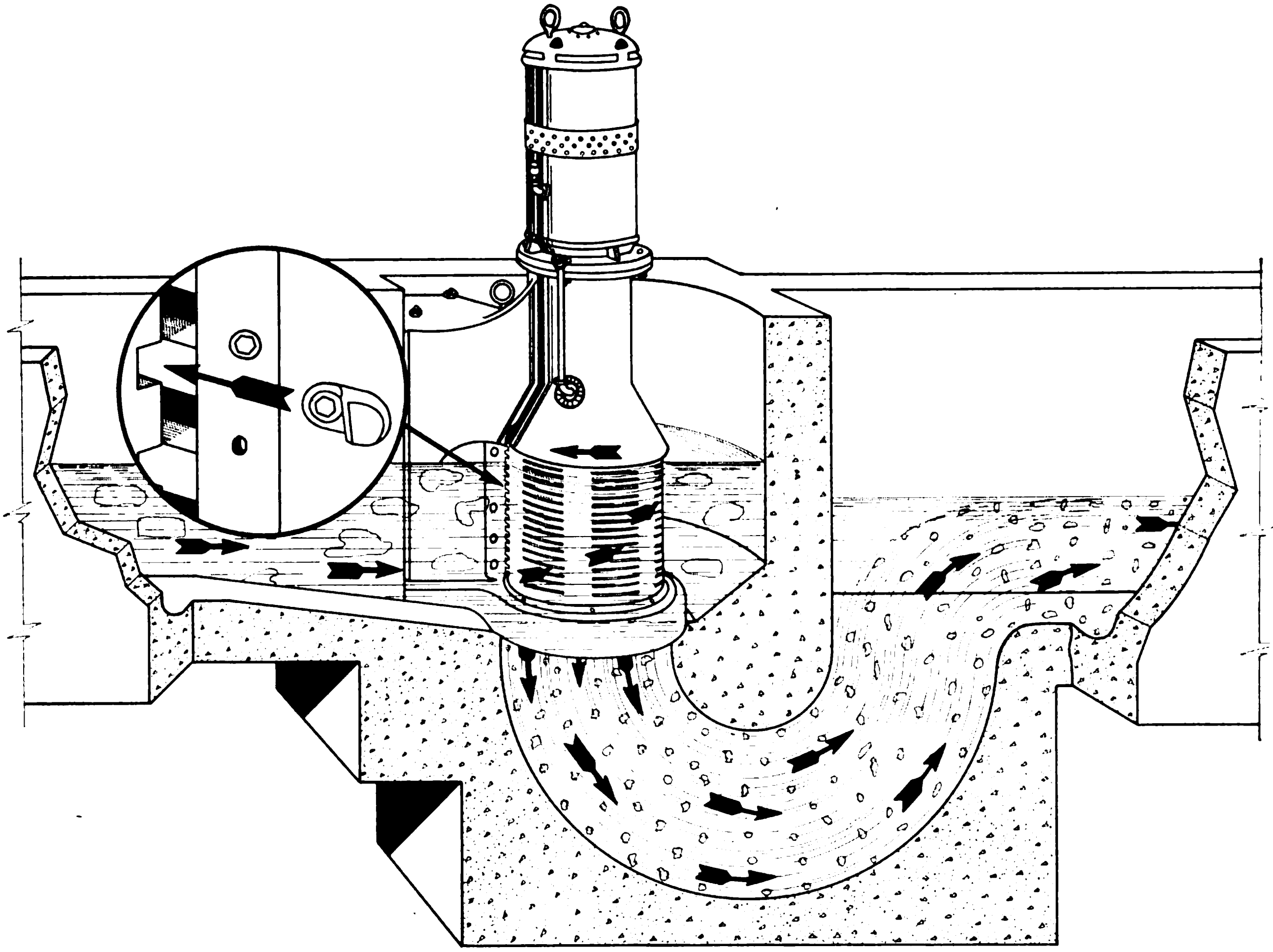


FIGURE 40. *Sectional drawing of comminutor.*

55. Disposal of Screenings

Screenings from bar or other coarse screens contain putrescible material and should be disposed of in a sanitary manner.

a. GRINDING. Where equipment is available, grinding is the best method of disposal. Accumulated screenings are ground once or twice during each operating shift. Manufacturers' instructions for starting water and screenings feed and for cleaning the machine must be carefully followed. The grinding teeth should be resharpened before wear becomes excessive.

b. INCINERATION OR SANITARY FILL. Where incinerators or sanitary fills are available, screenings may be disposed of with the garbage or post refuse. Collections are necessary daily to avoid odor nuisance and flies. Under no circumstances may screenings be disposed with garbage used for hog feeding or plowing under in cultivated land.

c. BURIAL. Disposal by burial by the plant operator may be necessary if other means are not available. The method used is similar to that for garbage disposal by sanitary fill TM 5–634 (when published), except on a much smaller scale.

56. Records

The following records are kept:

a. MONTHLY. Monthly reports include the following:

(1) Total cubic feet of screenings per month.

(2) Calculated cubic feet of screenings per million gallons.

(3) Method of disposal.

b. DAILY. Daily records show cubic feet of screenings removed.

Section IV. PREAERATION AND VACUUM FLOTATION

57. Preaeration

Most preaeration units in Army sewage plants have been installed to aid in grease removal by causing

some of the grease to float. Studies at Army posts in 1943 showed that preaeration for 10 to 15 minutes does not perceptibly reduce the grease content of the primary settling tank effluent. Normally, grease settles with the sludge in the primary, but it rises to the surface with preaeration. However, existing preaeration units may be used to keep sewage fresh through the primary settling tanks, reducing odors and improving the effectiveness of secondary treatment. Preaeration units also are effective grit chambers, and those with detention periods of 1 to 2 hours have been installed specifically for BOD reduction.

a. Construction. Aeration is accomplished either by diffused air or mechanical aerators in rectangular tanks with a detention period of approximately 15 minutes. Provision is usually made for skimming the grease from the aeration tank although the grease is sometimes removed as scum in the primary settling tanks.

(1) Figure 41 shows two parallel preaeration units with air diffusers located near the inner walls producing a spiral motion. The slatted baffles produce a quieter zone in the outer half of the tanks. Grease is skimmed by hand towards the far end into cans placed in the receiving box.

(2) Figure 42 shows a cross section of a mechanical aeration tank for grease removal. Air is entrained in the flow to the pump and forced downward to the bottom of the tank. Grease is collected in the troughs on two sides by mechanical skimmers.

b. Operation. Preaeration units are operated when their use is justified for maintaining the sewage in a fresh condition or for grit removal. Otherwise, the unit may be bypassed. Use of power and labor is not warranted solely for grease oftation.

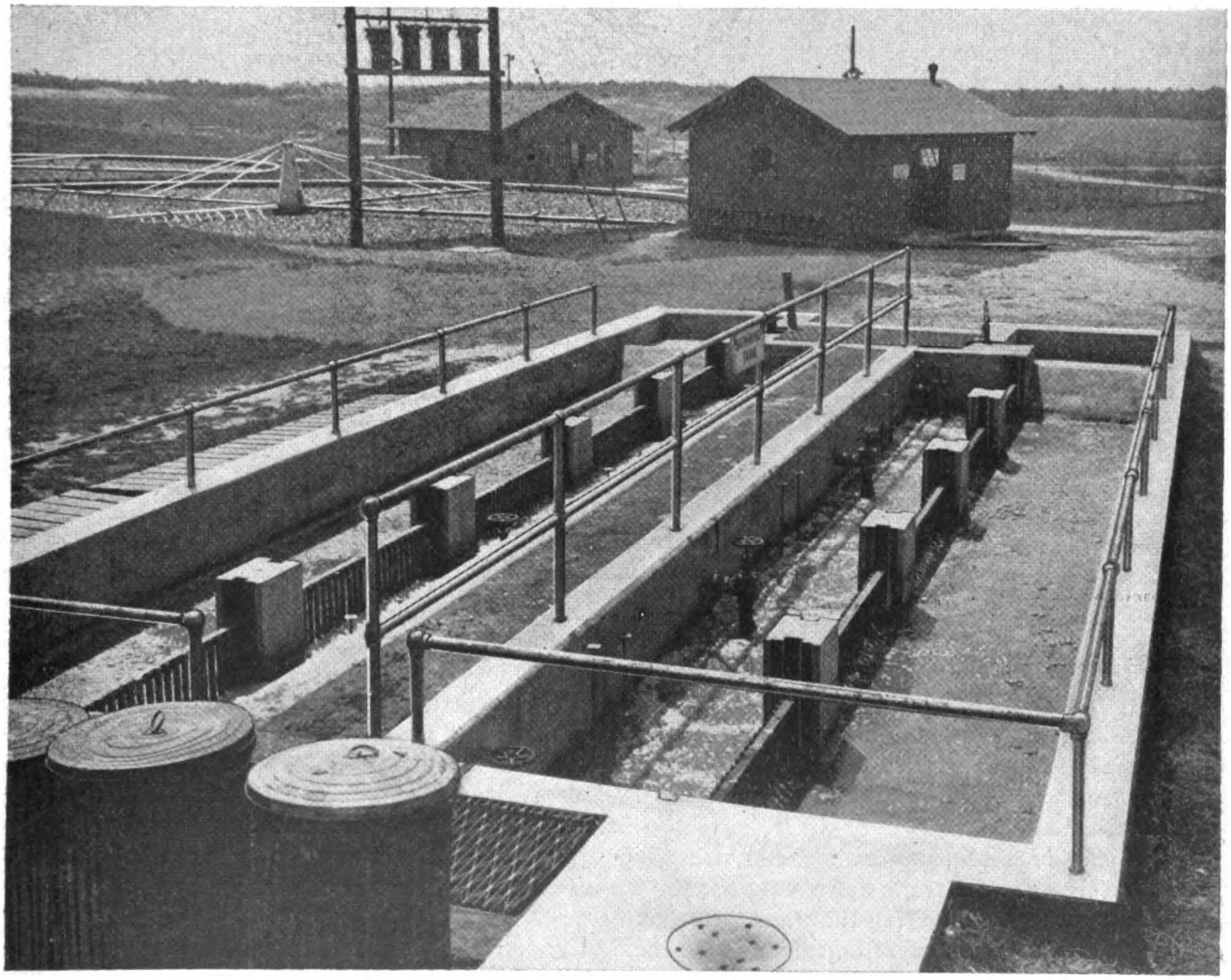


Figure 41. *Parallel preaeration units of diffused-air type.*

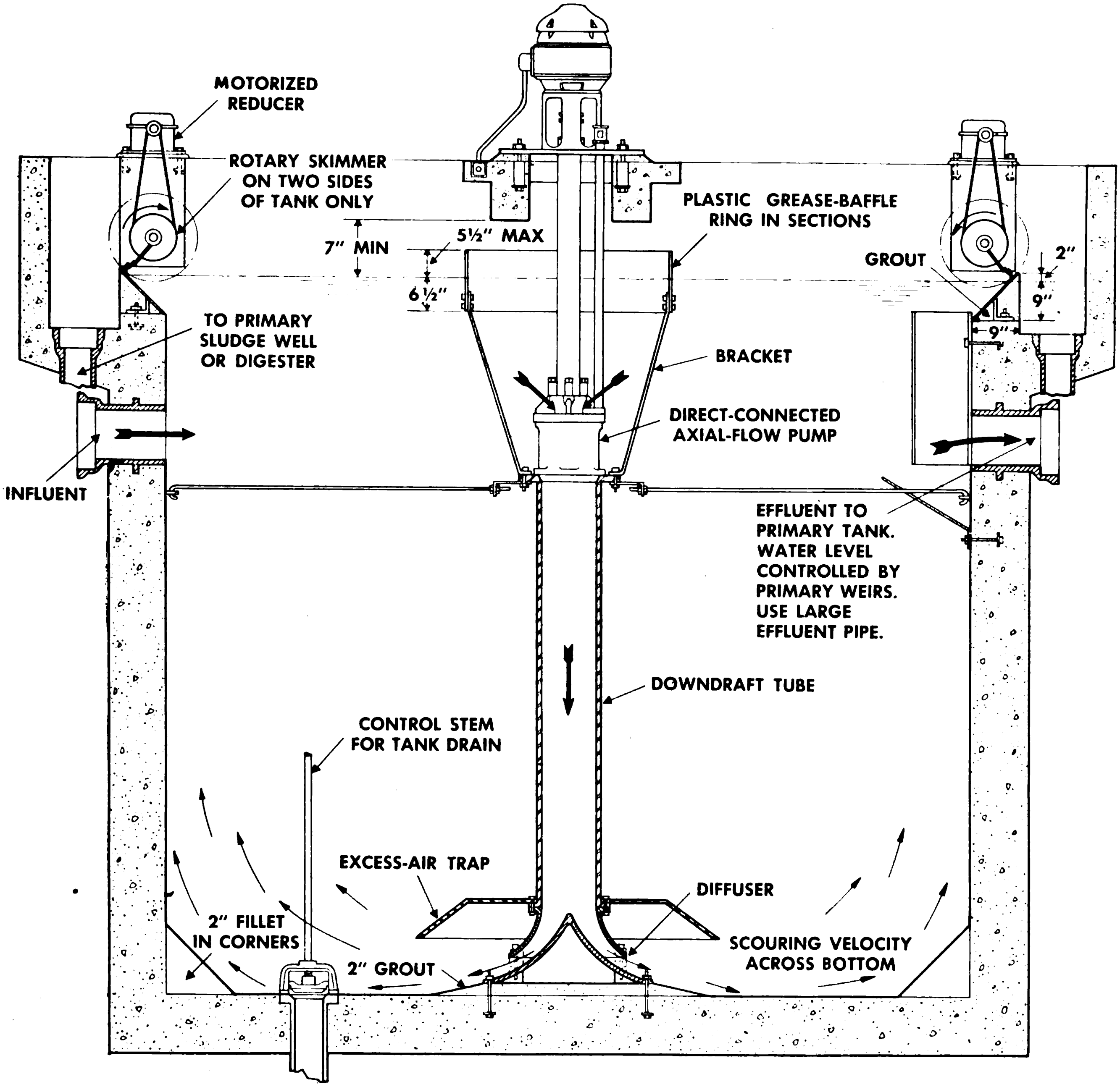


FIGURE 42. *Mechanical aeration tank for grease removal.*

(1) Aeration must be continuous to prevent deposit of organic solids and clogging of diffusers. Grease must be skimmed each shift. Sidewalls and troughs must be cleaned daily to prevent odors from rancid grease.

(2) Depth of grit in bottom of tanks is determined weekly. Grit deposits are removed when 4 to 6 inches deep by emptying tank and shoveling out the grit. Accumulation of organic solids in the grit may cause septic action if the grit becomes too deep.

(3) Although the amount of air input normally cannot be controlled, dissolved oxygen tests (use inhibitor as shown in par. 166) should be made weekly on the influent and effluent. If no dissolved oxygen is found, the immediate oxygen demand (par. 167) of the influent and effluent should be determined as a measure of the effectiveness of the process.

c. MAINTENANCE. Preventive maintenance inspections and services for aeration tanks given in TM 5–666 apply to preaeration tanks.

d. Records. Total volume of skimmings and grit removed are reported on monthly operating log. Daily records contain the following:

(1) Daily quantity of skimmings.

(2) Dates of grit removal, and quantities.

(3) Results of dissolved oxygen (DO) and immediate-oxygen-demand tests.

58. Vacuum Flotation

Vacuum-flotation units, vacuators, have been installed principally for grease removal. As with simple preaeration units, tests have shown that little more grease is removed by vacuum flotation plus primary settling than by primary settling alone. Vacuators can remove much of the settleable solids along with grease and have been used in place of primary settling. Because of the short detention period (15 to 20 min.), sewage is kept fresh. Vacuators also serve as grit chambers.

a. Construction and operation. Sewage is first aerated by a mechanical aerator for 1 minute or less. The large bubbles are allowed to rise in a small chamber and dispel to the atmosphere. The sewage then rises into the vacuator through a center feed. (See fig. 43.) A vacuum of 9 inches mercury or 10 feet, 3 inches water is maintained in the unit by a small vacuum pump.

(1) Dissolved and entrained gases are released and carry the solids to the surface, the grit dropping to the bottom. Grit and scum are removed as in circular settling tanks (par. 73); operation of the collector mechanism is continuous. A sight glass and interior light are usually provided for observing operation. Scum is discharged to a box with a

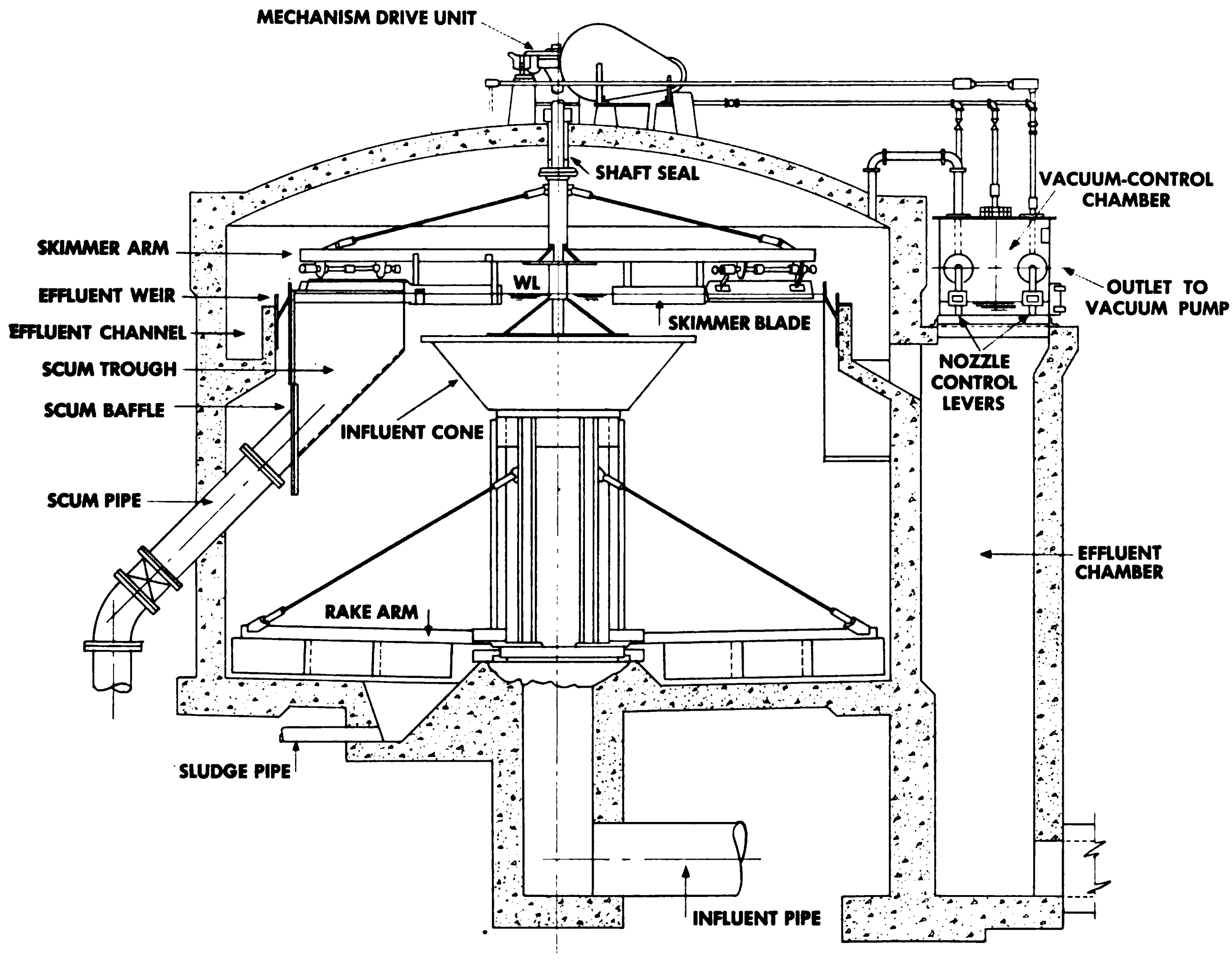


Figure 43. *Vacuator.*

submerged inlet to provide a vacuum seal; it usually has much concentrated solid matter which requires dilution if pumped to the digester. Use of supernatant for this dilution assists seeding and reduces digester scum formation.

(2) Disposal of heavy scum by sanitary fill or incineration may be satisfactory. Grit and heavy organic solids are removed daily for burial. If the full vacuum is not maintained, sewage does not flow through the unit, requiring an automatic bypass arrangement between influent and effluent boxes.

b. MAINTENANCE. Vacuator mechanism maintained according to instructions for similar settling-tank sludge-removal equipment given in TM 5–666. All seals and joints are frequently inspected and maintained to prevent excessive air infiltration; any cracks in concrete sides or dome are repaired with asphalt sealing compounds.

c. OPERATING RECORDS. Total volumes of scum and grit and their disposition are reported on monthly operating logs. If vacuator is used in place of primary settling, analytical determinations for primary settling tanks are made and recorded. If scum is pumped to the digester, solids and volatile determinations are recorded the same as for raw sludge. The following daily records are kept:

(1) Vacuum, in inches of mercury.
(2) Daily quantity of scum.
(3) Daily quantity of grit.
(4) Estimated quantity of sewage bypassing vacuum-flotation unit.

Section V. METERING OF SEWAGE FLOW

59. Necessity for Metering

a. GENERAL. Operators must know at all times how much sewage is being treated for proper plant control and sampling. Such data provides valuable records for comparing plant efficiency and designing additions to the installation. Many methods of measuring liquids flowing in open channels and in pipes flowing full or partially full have been devised. Although some equipment requires elaborate and expensive apparatus, simpler, comparatively inexpensive methods are in use.

b. ELEMENTS. Metering devices are classed as primary elements which produce quantitative head variation (weirs, Parshall flumes, or Venturi tubes) and secondary elements which measure this head variation (float or staff gauges, indicating, integrating, and recording instruments). Every sewage plant must have some form of sewage-flow measurement. If complete gauging and recording equipment is not warranted, one of several simple devices may be used.

60. Types of Devices

a. WEIRS. (1) *General.* Weirs are regularly formed notches or openings through which water flows; they are classified according to shape as rectangular, triangular or V-notch, trapezoidal, and parabolic weirs. (See fig. 44.) Rectangular and V-notch types are most common. Further data on weirs is given in TM 5–660 (when published).

(2) *Installation.* If other means of measuring sewage flow have not been provided, a weir may be located in an influent or effluent channel at a point where backing up of sewage does not interfere with the hydraulics of the plant or sewer system. They should have a size and shape which maintain a minimum-flow head of at least ½ inch. Figure 45, showing weir and float, indicates a separate compartment for the float; a float compartment may be made by chipping an opening in a sewer tile set in the channel. The float must be located at least two and one-half times as far upstream as the maximum flow depth over the weir to be safely beyond the effect of surface contraction. If the flow velocity immediately above the weir location is greater than ½ foot per second, a stilling box is needed.

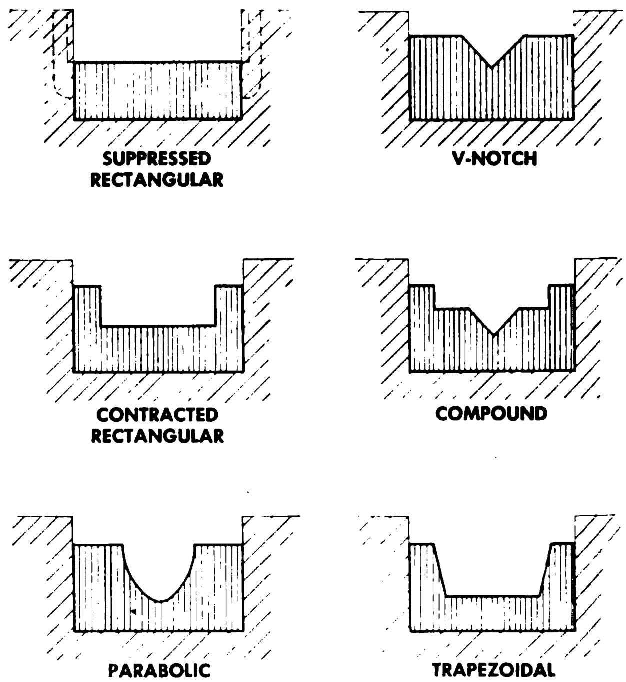


FIGURE 44. *Types of weirs used as differential devices in measuring flow in open channels.*

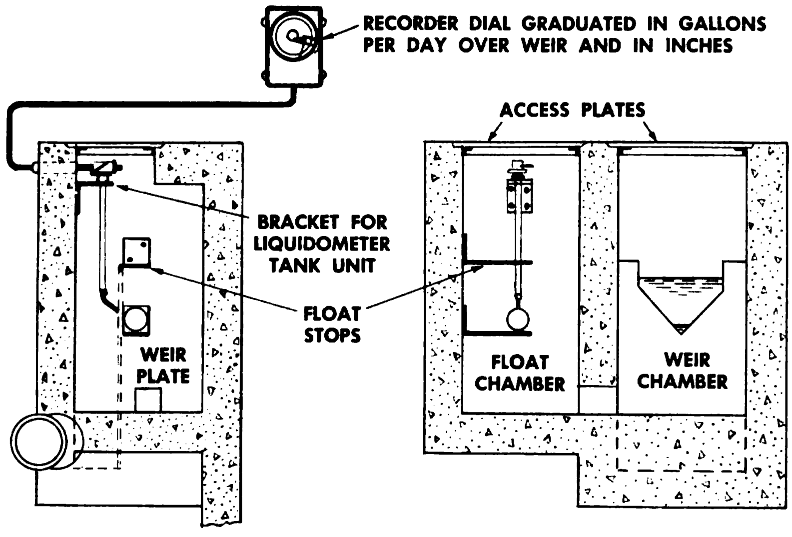


FIGURE 45. *Typical V-notch weir and float chamber.*

b. PARSHALL FLUME. In open channels, the Parshall flume is often used for measuring flows. This flume has an open and constricted channel in which difference in sewage elevation above and below the contraction can be accurately translated into rate of flow. The surface rise is usually indicated and recorded by the same type equipment as used with weirs. The Parshall flume is better than the weir in that is is self-cleaning, can handle a wide variation of flow, and does not require as great a head loss; it is particularly useful where the available head is limited. The tabulation below shows the various dimensions required of Parshall flumes, while discharge is given in table I.

DIMENSIONS IN FEET AND INCHES

Throat width (feet)	A		⅔A		B		C		D		E	F	G
	ft	in	ft	in	ft	in	ft	in	ft	in	ft	ft	ft
0.5	2	1¼	1	4⅞	2	-----	1	3½	1	3½	1	2	4½
1.0	4	6	3	-----	4	4⅞	2	---	2	9¼	2	3	9
2.0	5	---	3	4	4	10⅞	3	---	3	11½	2	3	9
3.0	5	6	3	8	5	4¾	4	---	5	1⅞	2	3	9

Note. Capital letters in column heads refer to figure 46.

When ratio of H_b to H_a (fig. 46) exceeds 0.6 for flume widths less than 1 foot, or 0.7 for flume widths 1 foot or more, a submergence correction must be applied. (See Bulletin 1683, U. S. Department of Agriculture.) Figure 47 shows a typical installation of a Parshall flume, float, and recording meter. Various water-level recorders are used in this type of installation.

c. DOSING CYCLE. A method of measurement in plants having a filter dosing chamber is by installing a float-actuated mechanical device for counting the dosing cycles. Sewage elevations in the dosing chamber and rate of flow to the chamber during the dosing period must be known to convert dosing-cycle count to an estimate of flow. This method is widely used but is subject to considerable error because of variations in the rates of flow to the chamber. The dosing siphon may remain in operation during high flows, or the siphon may fail to air lock, permitting continuous flow to the filter without counter operation.

d. KENNISON NOZZLES. Kennison nozzles measure flow through partially filled pipes and open channels having a wide range in flow rates. This device is particularly successful for measuring raw sewage and sludges. Figure 48 shows a nozzle of this type; dimensions and capacities of Kennison nozzles are given in the following tabulation.

DIMENSIONS AND CAPACITIES OF KENNISON NOZZLES

Inlet diameter (inches)	Capacity		Length (inches)
	Cubic feet per second	Gallons per day	
6	0.42	275,000	12
8	.70	450,000	16
10	1.25	800,000	20
12	2.00	1,250,000	24
16	4.20	2,700,000	32
20	7.00	4,500,000	40
24	11.50	7,400,000	48

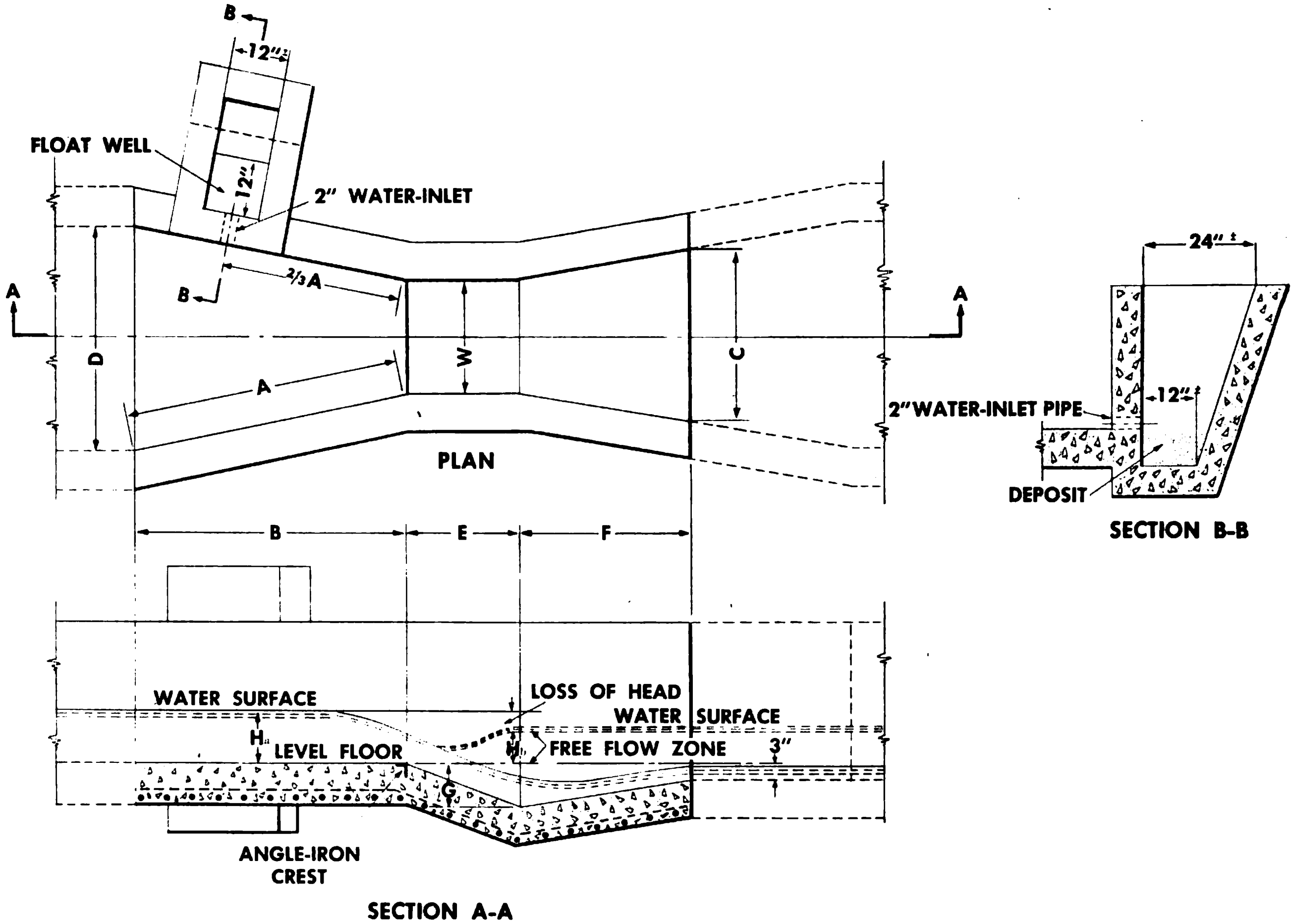


FIGURE 46. *Plan and section of Parshall flume. Dimensions given in paragraph 60.*

e. VENTURI METER. The Venturi meter is commonly used for measuring flows in pipes under pressure. The Venturi tube, which is the essential part of the meter, is a constricted element set in the pressure line. Measurement is made by determining the differential in pressure at the inlet and constricted portions of the tube; this differential may be measured by floats in wells connected to the two pressure points by manometers or other methods. Figure 49 shows a typical Venturi-tube installation; additional information on Venturi meters is given in TM 5–660 (when published).

f. VENTURI FLUME. The Venturi flume is sometimes valuable for measuring flow in sewers because special structures may be required for other devices. The flume uses much the same principle as the tube, flow being indicated by the differential in head at inlet and constricted points. Description and design data of the flume are given in handbooks on hydraulics or Proceedings of the American Society of Civil Engineers, September, 1935.

g. SECONDARY ELEMENTS. Secondary metering elements are the instruments which translate the primary measurement of head or head differential to terms of flow. They may *indicate* the momentary rate of flow, *record* the rate of flow on a clock-driver chart, *integrate* or *totalize* the volume of flow, or accomplish any combination of these functions. The instrument must be designed or calibrated for the individual type and size of primary meter (weir, flume, or Venturi). The simplest type of indicating instrument is a float-mounted staff gauge located directly over the float well. For calibration of staff gauges for weirs, formulas and tables in TM 5–600 (when published) should be used; for Parshall flumes, table I.

61. Operation and Use

Many posts equipped for secondary treatment and chlorination have the main sewage-metering device located in the plant influent line. Since rate of flow at the point of chlorination usually differs from that at the influent, an indicating type meter is needed near the chlorinating chamber for accurate control of chlorine dosage; weir with a float gauge or

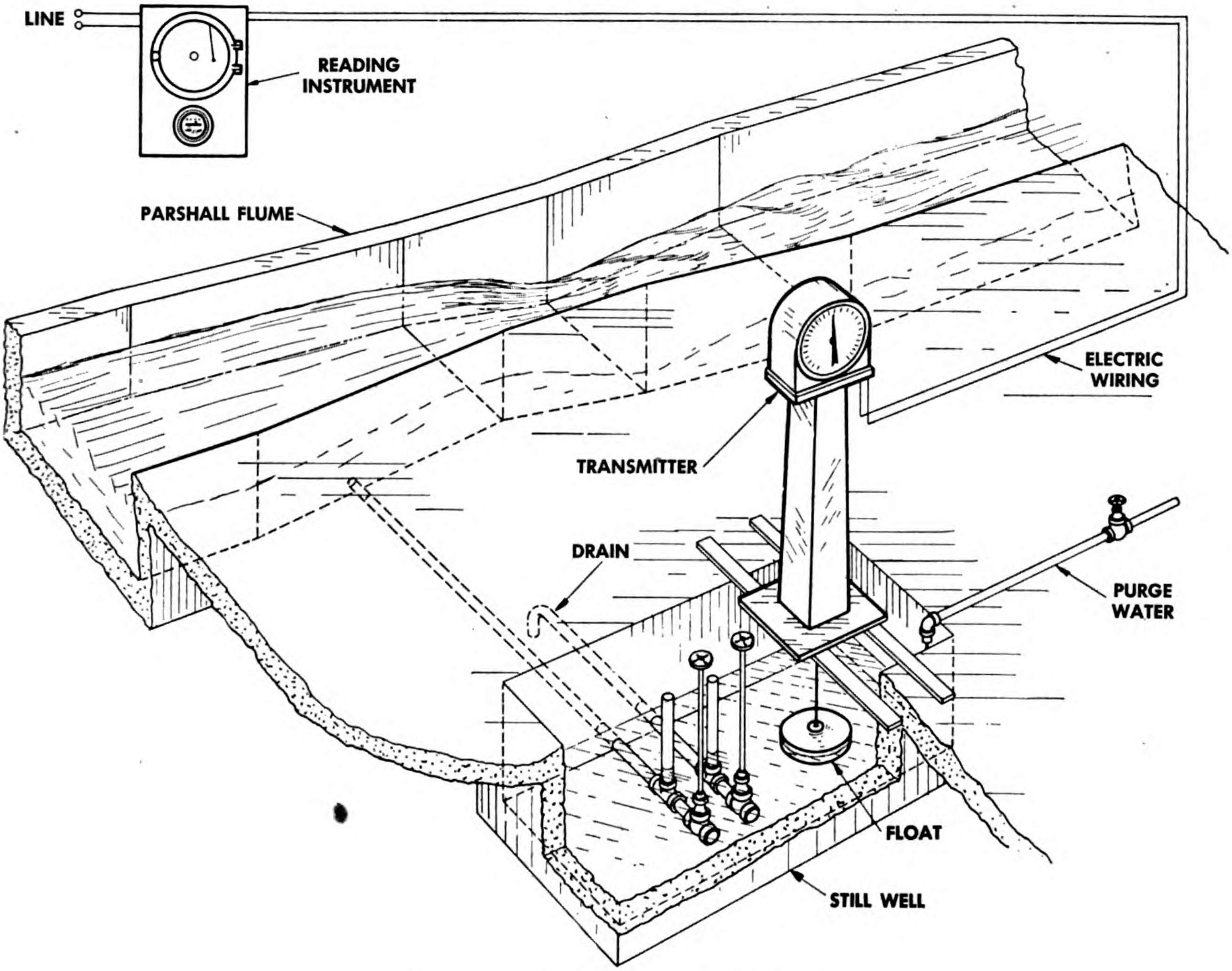


FIGURE 47. *Parshall flume with metering device.*

water-level recorder is enough. The weir may be set in the effluent channel if it does not back up sewage into the treatment units. Location at either the influent or effluent end of the chlorine contact chamber may be made, the effluent end being preferred because the chamber is usually large enough to eliminate high approach velocities. A weir box on the effluent line may be necessary.

a. PRIMARY ELEMENTS. Sewage solids accumulate in float or stilling wells, Venturi rings, and behind weirs. Instructions in TM 5–666 must be followed to insure meter accuracy and avoid odors.

b. SECONDARY ELEMENTS. Instruments providing only flow indication are read hourly during plant attendance. Total daily flow and maximum and minimum flows are estimated from these readings. Integrators are read each day at the same time, preferably at 0800 hours, and total daily flow is obtained by subtracting previous day's reading and multiplying by constant shown on meter case. Record charts are changed daily at same time in-

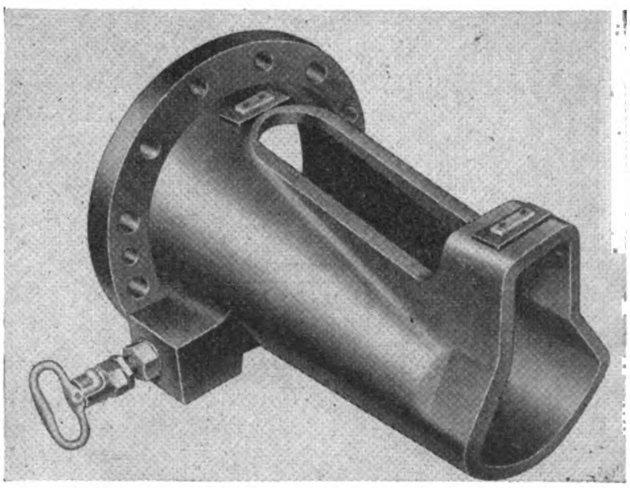


FIGURE 48. *Kennison open-flow nozzle.*

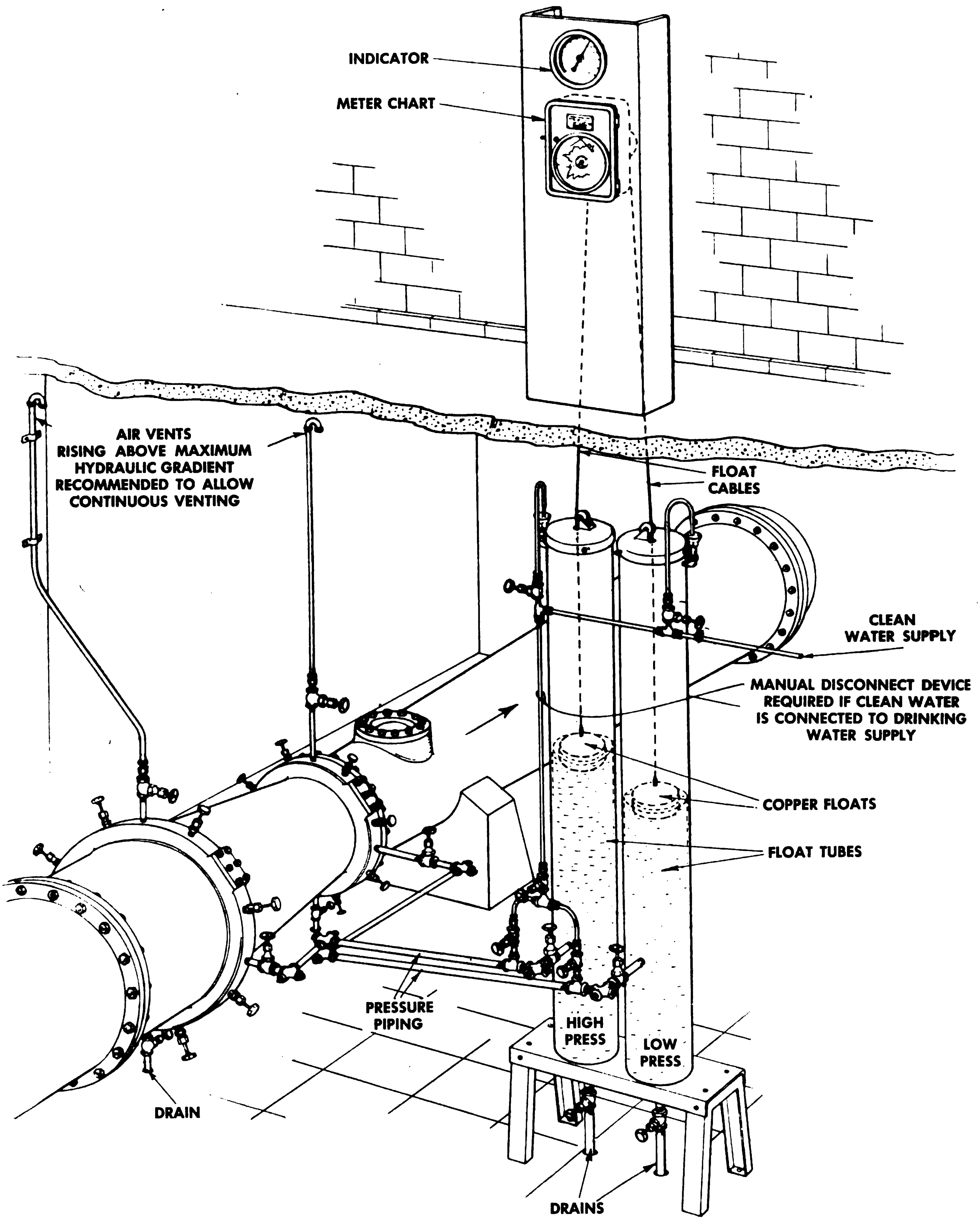


FIGURE 49. *Venturi-tube installation with connection to meter.*

tegrator is read. Maximum and minimum flow readings are obtained from the chart. These devices are maintained as directed in TM 5-666.

c. TIMING PUMP OPERATION. Estimation of flow by timing pump operation is sometimes desired, especially in high-capacity filter plants and in activated-sludge plants where recirculation of effluents is done. Calibration of the pumps is necessary for this operation. Calibration may be made by the following volumetric method:

(1) Time the pumping from a tank or sump after closing the inlet.

(2) Time the rise of sewage in a tank into which the pump is discharging. The head during this test must be about the same as during normal pump operation.

62. Units of Measurement

Sewage may be measured either by rate of flow (volume passing a given point in a unit of time) or by total volume. Common units and equivalents are as follows:

a. Cubic foot per second (cfs), used in recording rate of stream flow and flow in storm sewers.

1 cfs = 448.83 gallons per minute (gpm)
1 cfs = 646,315 gallons per day (gpd)

b. Gallons per minute (gpm), used in pump output and sewer flows as a rate of flow.

1 gpm = 0.00223 cubic feet per second
= 1,440 gallons per day

c. Million gallons per day (mgd), used in total daily flows and may be used to express rate of flow.

1 mgd = 1.547 cubic feet per second
= 694.4 gallons per minute.

d. Thousand gallons, per day, per month, or accumulative during fiscal year (for reporting purposes).

1,000 gallons = 0.001 million gallons

e. Cubic foot, used in storage volume.

1 cubic foot = 7.48 gallons

63. Records

The following daily records are recorded on the monthly report.

a. Total flow in 1,000 gallons per day.
b. Maximum rate of flow in 1,000 gallons per day.
c. Minimum rate of flow in 1,000 gallons per day.

Section VI. IMHOFF TANKS AND CLARIGESTERS

64. Design and Purpose of Imhoff Tanks

The Imhoff tank (fig. 50), commonly used at Army installations, is a two-story structure with an upper (flowing-through) compartment for primary settling and a lower one for sludge digestion. Solids settling from the sewage pass through a slot in the hopper bottom of the flowing-through compartment. Sludge digestion produces gas which passes upward, being diverted at the slot to gas vents next to the settling compartment. This permits a settling unhindered by rising gas which is more efficient settling than in septic tanks. The sludge compartment is not heated. Although provisions is sometimes made for gas collection, it is generally ventured to the atmosphere. Digested sludge is withdrawn by gravity or pumping through a sludge line from the bottom of the sludge compartment. Imhoff tanks for Army installations usually provide 2½-hour detention for average flow in the settling compartment and a sludge-holding capacity of 3 to 4.5 cubic feet per capita.

65. Operation of Settling Compartment

a. REGULATION AND REVERSAL OF FLOW. Proper distribution of the influent to the settling compartments is essential to efficient settling.

(1) Where two or more units are installed, flow is distributed between units by adjusting the influent gates. Properly placed dividing lines of bricks or triangular blocks of concrete may sometimes be used in the influent channel to divide the flow. Leveling of outlet weirs is necessary to equalize distribution between units.

(2) Many long tanks, where most of the solid may tend to settle at the influent end, have channels to reverse the flow, using the entire digestion space to full capacity. If uneven sludge distribution occurs, flow must be reversed each month.

(3) Settling compartments have influent and effluent baffles, which should not extend more than 18 inches below the sewage surface. The influent baffle distributes incoming flow more equally across the section of the compartment.

b. SCUM REMOVAL. Influent channels are kept free from grease, scum, and gritty deposits by scraping sides and bottom once daily or oftener if necessary.

(1) Floating material on the surface is skimmed off several times daily. A convenient skimmer can be made on a pole long enough to reach all parts of the tank. A ¼-inch-mesh galvanized screen attached to a heavy wire ring and formed into a 10-inch-square basket with a tapered bottom is attached to the end of the pole. A skimmer with a perforated scoop on a pole is handy for skimming

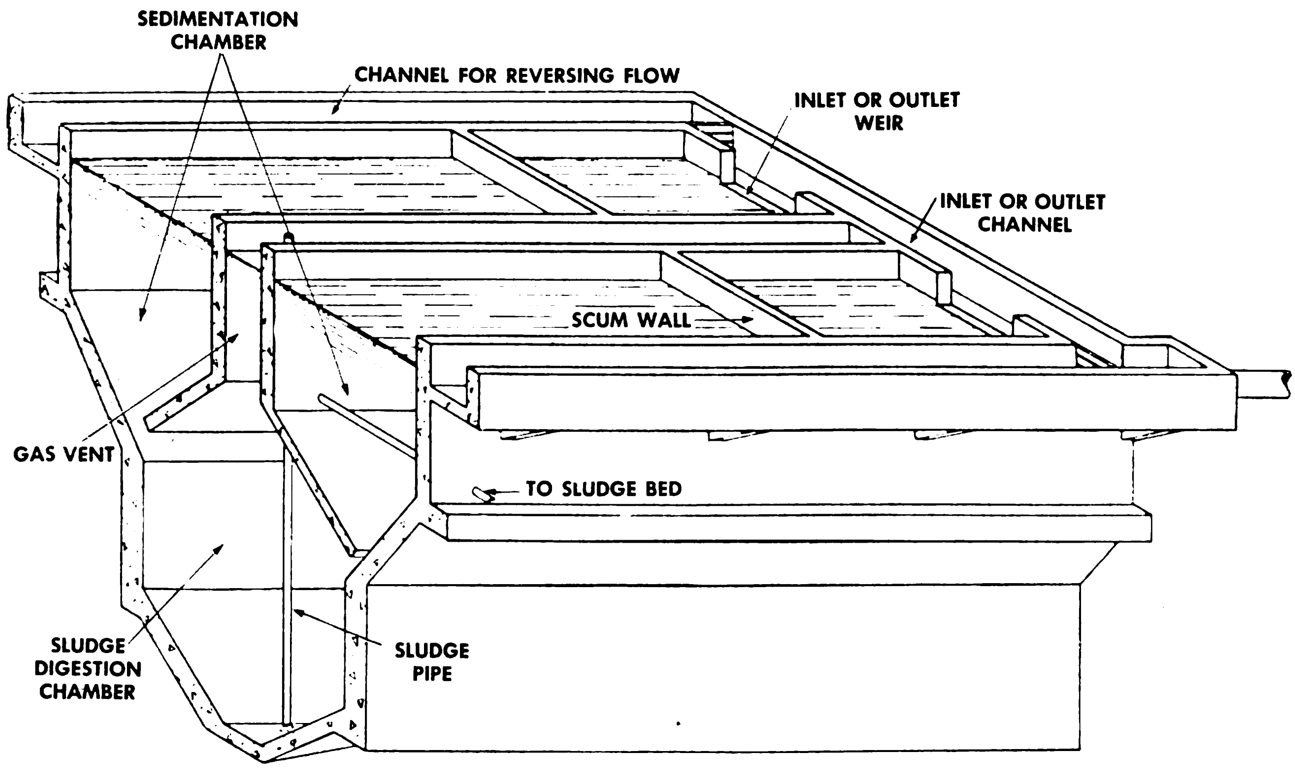


FIGURE 50. *Sectional view of Imhoff tank.*

influent channels. Construction of these tools is illustrated in figure 51. In skimming, the sewage must not be disturbed so much that skimmings pass under the baffles.

(2) A continuous spray of water helps settle floating solids. (See fig. 52.)

(3) Grease and scum adhering to tank walls at the water line are removed daily by hosing and scraping to prevent odor nuisance.

(4) Placing skimmings in the gas vents is not recommended since it is easily overdone and causes trouble from odors. Petroleum oil must never be placed in gas vents.

(5) Skimmings may be buried or burned in an incinerator; they must be promptly covered with earth, receiving an additional 6 inches of earth after the first 24 hours. At posts operating a sanitary fill, the skimmings are collected in a covered container and transported daily to the fill.

c. CLEANING. All walks, wall tops, and exposed interior walls are washed down at least once each day.

d. SLOPING BOTTOM AND SLOT. Solids adhering to the sloping bottom of the upper compartment must be pushed into the slots by a squeegee once a week or oftener if necessary. This squeegee can be made with a long pole and rubber belting mounted on a cross piece of suitable width. (See fig. 51.) At the same time, the slots must be cleaned by dragging along the slot with a 3-foot heavy chain mounted on a pole. (See fig. 53.) Excessive stirring, which interrupts normal settling, must be avoided in these operations.

66. Operation of Digestion Compartment

The digestion compartment operates similarly to those for separate sludge digesters, which are discussed in paragraph 78.

a. CONTROL OF SLUDGE LEVEL. The sludge compartments are normally kept quite full of sludge, but not above a level 2 feet below the slots. When the settling-compartment slot is not properly trapped, holding the sludge level much lower to prevent sludge solids from passing upward through the slots may become necessary. Withdrawing small amounts of sludge monthly is better practice than drawing off large quantities at longer intervals. Only well-digested sludge is drawn, with enough digested sludge left to provide proper seeding and prevent acid digestion and foaming. Not more than half the depth of sludge in the tank may usually be removed at any one time. This procedure must be changed in northern climates during the winter because of slower rates of digestion and

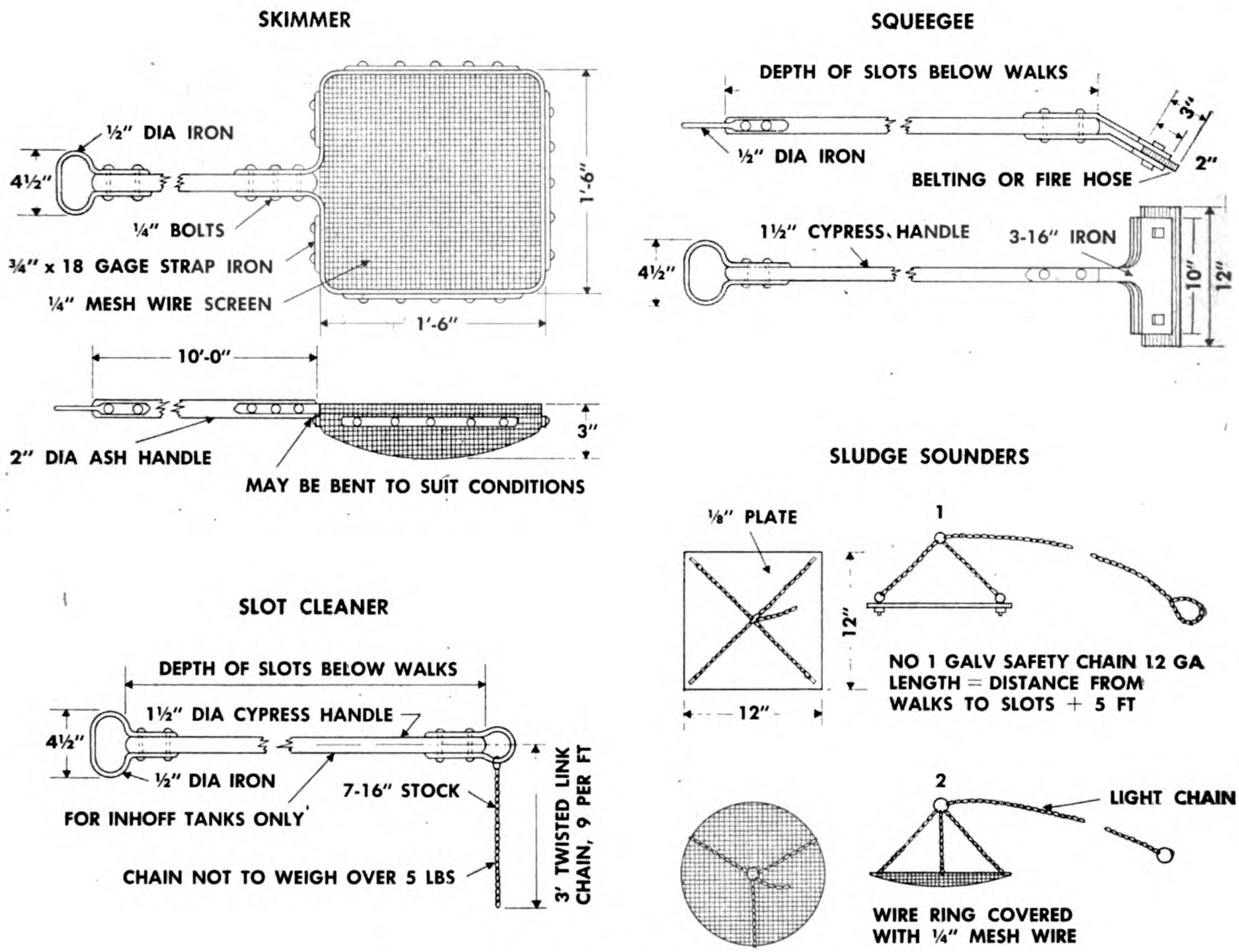


FIGURE 51. *Homemade tools for sewage treatment plants.*

lack of sludge-drying facilities. The sludge level must be lowered during the summer and autumn to allow room for the winter accumulation. At some plants, withdrawal must be regulated according to availability of drying beds. Sludge must be drawn down in advance of long rainy seasons to allow adequate capacity.

b. DIGESTED-SLUDGE REMOVAL. Digested sludge is black, granular, has an inoffensive tarry odor, a pH normally above 7.0, and a volatile-solids content less than 55 percent (dry basis). It drains and drys readily on sand beds.

(1) Digested sludge must be drawn slowly to prevent forming a cone within the sludge and removing partially digested sludge and sewage. After sludge is drawn, the lines are flushed out and filled with water (unless there is danger of freezing) to prevent drying and hardening of solids within the pipes.

(2) If sludge clogs the withdrawal pipe, flow may be started by agitating the sludge with long rods through the slots, gas vents, or the sludge riser pipe. Recirculated effluent or water under pressure (not connected to potable system) may be used through hose immersed in the sludge riser pipe. Opening and closing the sludge valve also may relieve clogging.

c. MEASUREMENT OF SLUDGE DEPTH. When the plant is operating near capacity, depth of sludge in the sludge compartment is determined at inlet and outlet ends of the tank once each week. If less than 75 percent of sludge-compartment capacity is in use, monthly tests are adequate. Measuring depths with a pitcher pump is better than the plate or disk method, which requires considerable experience and is not always satisfactory. These methods are described below.

(1) A pitcher pump is equipped with a rubber suction hose, weighted on the end with length

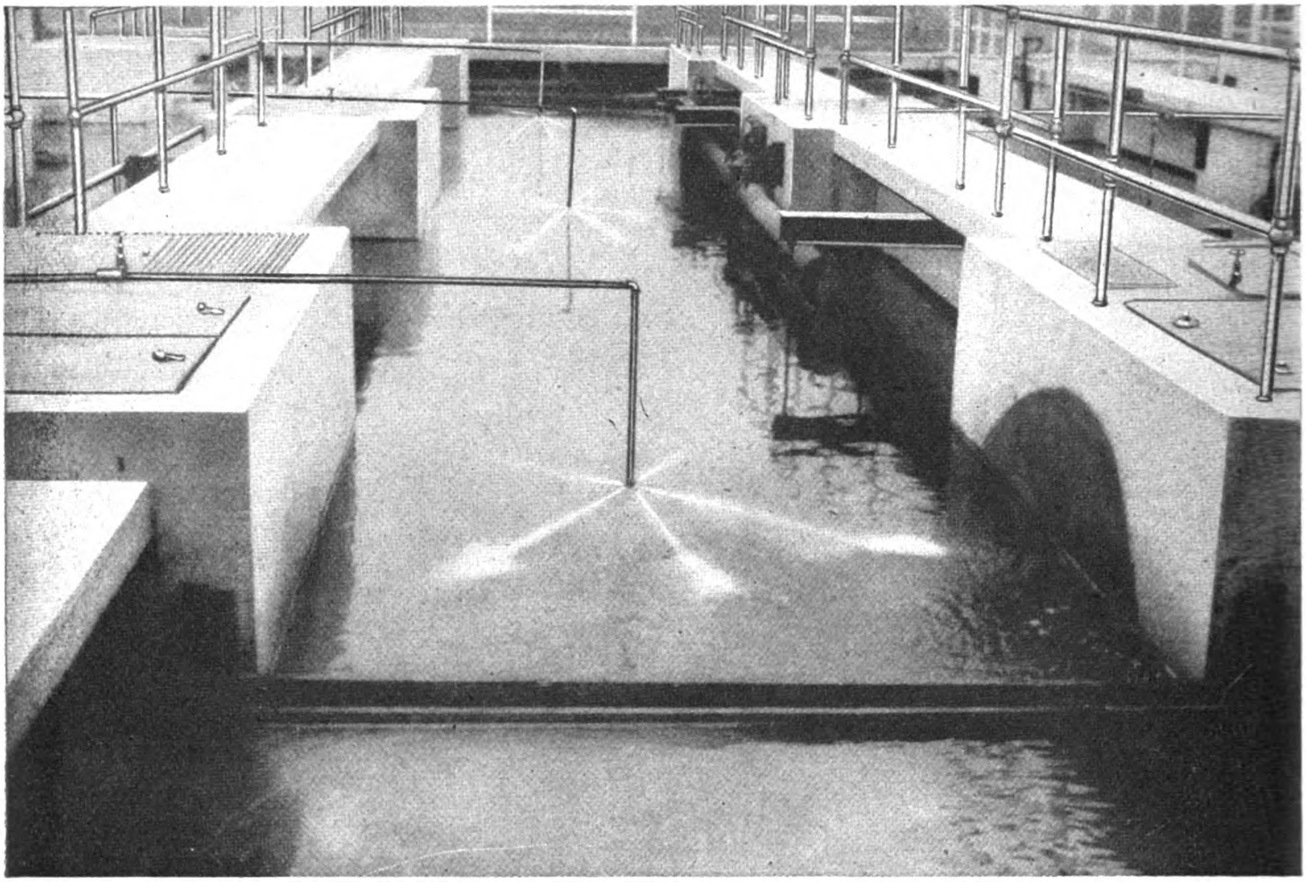


FIGURE 52. *Water spray used to settle floating solids. Final effluent is used for spray.*

marked on the hose at 2-foot intervals. The hose is lowered gradually through the slot in the settling compartment while the pump is operated. The length of hose immersed when sludge first appears equals the sludge depth.

(2) Another pitcher-pump method uses a rubber suction tube graduated and marked as above but weighted by a 4-foot steel pipe which is an integral part of the suction line. Sludge depth is found the same as before except that the hose is lowered through the gas vent instead of the settling-compartment slot.

(3) A sludge sampler similar to the one shown in paragraph 157 may be used. The sampler is lowered through the gas vent into the sludge compartment and samples taken at consecutively deeper points until the sludge level is reached.

(4) An iron plate on a weighted wood block 12 to 18 inches square is attached to a graduated wire or chain and lowered through the gas vent. When the sludge is reached, downward movement of the plate stops and the distance from the surface to the sludge level is determined.

(5) If the scum in the gas vents is not too heavy, a wire loop, 12 or 15 inches in diameter, covered with a disk of ¼-inch-mesh wire and suspended from a light chain at three points may be used in place of the plate.

d. GAS VENTS. Surface of gas vents must be broken up and wetted once each week or oftener if necessary to allow escape of gas and to facilitate scum digestion. One or more of the following methods may be employed:

(1) Work scum with rake, hoe, or other suitable tool.

(2) Hose scum with water under pressure, using a fine spray. Do not use large volumes of water which start currents upward through the slots.

(3) Keep the scum wetted down with sewage or preferably liquor from the digestion compartment by using a portable pump. Avoid using large quantities of water.

(4) When heavy dry scum is 2 or 3 feet deep, remove it with shovels or forks and place it on drying beds.

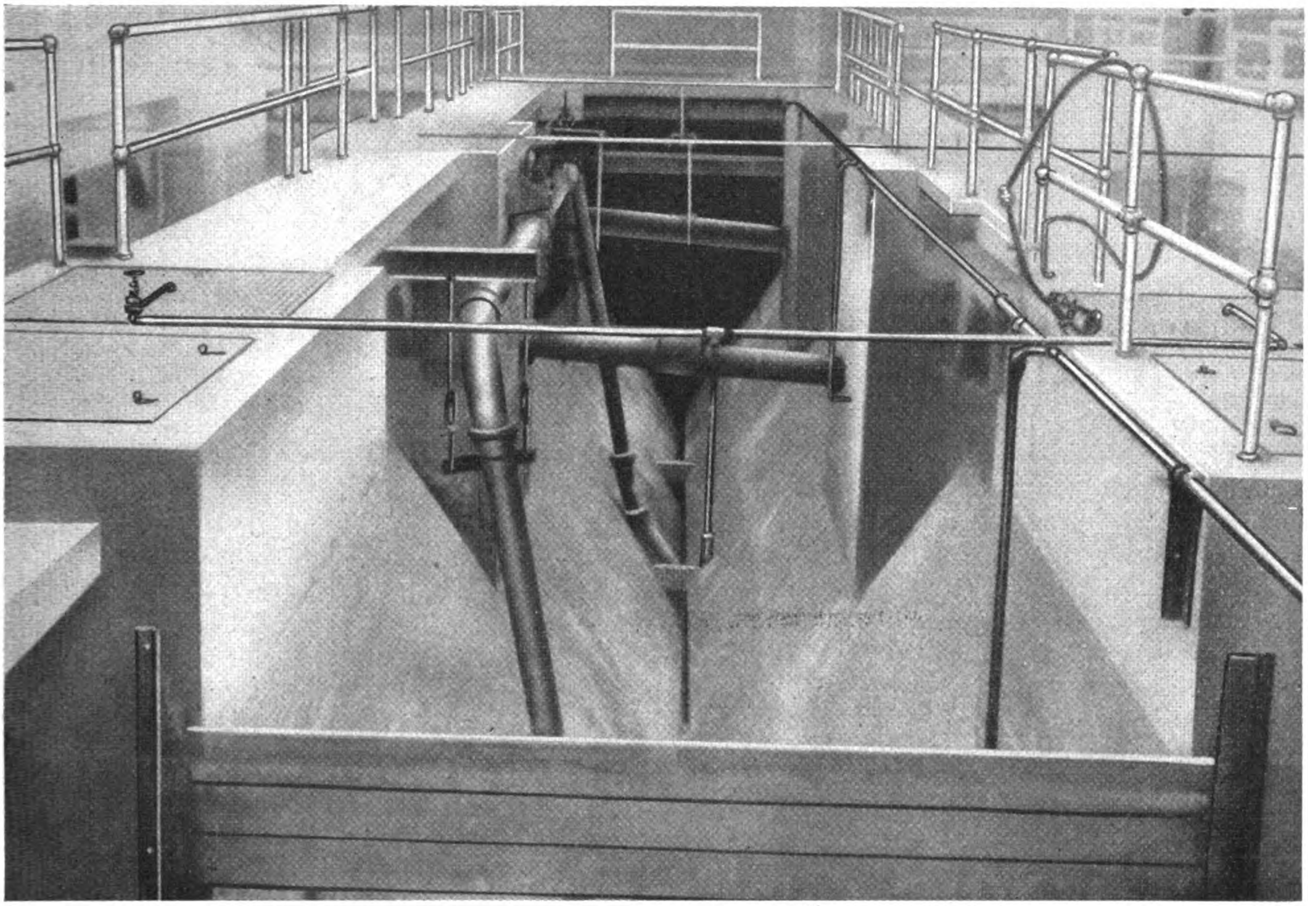


FIGURE 53. *Empty flow-through compartment. Slope must be squeegeed; slot is cleaned with chain.*

e. FOAMING. Foaming is characterized by an excessive, frothy, odorous scum filling the upper part of the digestion compartment and gas vents and often rising through the slots; it is caused when raw solids accumulate faster than they digest. Foaming results in a predominance of the acid stage of digestion, a lowering of the pH, and rapid gas formation. The gas produced during foaming is high in carbon dioxide content and may not burn in boilers and heaters. The following conditions may induce foaming:

(1) Starting a tank without seeding the sludge.

(2) Low temperatures during winter, which impede digestion, followed by the higher temperatures of spring and summer.

(3) Excessive withdrawal of sludge.

(4) Insufficient digester capacity.

f. CONTROL OF FOAMING. Foaming can be prevented in most cases by careful operation. When foaming occurs, it may be controlled by one of the following methods:

(1) In starting a tank, use digested sludge if available to hasten normal digestion. (See par. 80.)

(2) Put tank out of service until the action subsides if more than one tank is provided. However, the increased load on the other tanks may cause foaming in them. The sewage in the settling chamber of the resting tank becomes septic and odorous. As an alternative to this method, reduce the flow to the Imhoff tank, avoiding a detention period of more than 6 hours. Avoid septic conditions in the settling compartment when the Imhoff tank is followed by aerobic secondary treatment.

(3) Break the foam by periodic heavy hosing or preferably a continuous fine spray of water. Do not add large quantities of water which forces an equal volume of septic liquor or foam up through the slots and harms the tank effluent.

(4) Apply sludge-compartment liquor or sludge from the hopper bottoms to the gas vents by an air lift or portable pump. This method tends to mix the foam with digested sludge.

(5) Paddle the foam in the vents with hose.

(6) Use hydrated-lime suspension if the sludge pH is below 6.5. Do not use pebble lime (also called unslaked lime or quicklime), or construction

lime. Prevent undissolved lime deposits in the digestion compartment, which hardens and is difficult to remove. Put lime in thin suspension into the sludge compartment through a pipe inserted into the gas vents at different points. Add enough lime to raise the pH to 7.0, determining the amount needed by trial addition of lime suspension to measured quantities of sludge or gas-vent liquor from the tank.

(7) Remove sludge during the foaming period if the sludge compartments are heavily loaded. Apply hydrated lime during the drawing to reduce offensive odor and fly breeding. (See par. 104.)

(8) In extreme cases, where digestion capacity is insufficient and additional construction is delayed, build temporary earth lagoons to provide further digestion capacity. Make these lagoons as deep as possible, and equip them for sludge removal to drying beds by gravity or pumping if length of probable service indicates a need.

67. Methods of Control of Imhoff Tanks

Nature and frequency of sampling and laboratory determinations are discussed in section XVII, chapter 4.

a. Settling compartment. In smaller plants, control of the settling compartment is guided by the settleable solids (Imhoff-cone) and pH determinations. In larger installations, these tests are augmented by those for BOD and suspended solids. Normal operation should bring about a settleable solids reduction of 90 percent or more, a suspended solids reduction of 50 to 70 percent, and a BOD reduction of 30 to 40 percent. Causes for lower efficiencies must be determined and corrected.

b. Digestion compartment. Control of the digestion compartment is guided by the weekly or monthly sampling of the sludge depth and by sampling of digested sludge at bottom of compartment before being drawn to the sludge beds. Tests for sludge pH are made at all plants, with total- and volatile-solids tests at larger plants as directed. Experienced operators can tell when a sludge is properly digested. When undigested, a small portion of sludge on a shovel looks sticky; when properly digested, it is granular in appearance and shows clear streaks when poured off shovel because of separation of water from solids. Degree of digestion can also be judged by the relative lack of objectionable odor and presence of tarry odor.

c. Oil in sewage flow. Oil in the raw sewage entering the Imhoff tank or other treatment unit creates a difficult problem. Waste from airplane and engine wash racks should be eliminated from the sanitary sewer system. Where this is not possible, adequately maintained traps must be provided at the rack. (See par. 28.)

68. Reports and Records for Imhoff Tanks

a. Monthly reports. Monthly reports of all data and analyses include the following tests.

(1) For influent and effluent, settleable solids and pH tests. Suspended-solids and BOD tests are given when required.

(2) Number of units in operation.

(3) Depth of a sludge below slots.

(4) Percent solid and percent volatile of digested sludge.

b. Daily record. The daily record includes the following items in addition to those required for monthly reports.

(1) Direction of flow through tanks.

(2) Record of skimming, slot cleaning, and scum breaking.

(3) Sludge removal, showing date, tank and hopper number, and volume in gallons.

(4) Remarks on unusual operating conditions such as foaming, need for lime application, etc.

69. Design and Purpose of Clarigesters

The clarigester (figs. 54 and 55) is a single two-story structure in which two separate operations take place: settling of solids in the upper compartment and their digestion in the lower. Preventive maintenance of the unit is covered in TM 5-666. Its mechanism allows better control, provides for heating the sludge, and is generally more flexible in operation than the Imhoff tank.

a. Upper compartment. Sewage enters the central feed well of the upper compartment and settled sewage flows over the weir near the rim of the tank. Solids settle in the upper compartment and are raked to the center mechanically for discharge through a sludge seal into the lower compartment where they are stored to permit digestion. The motor-driven mechanism has two radial arms with raking blades which sweep the upper surface of a dish-shaped floor that divides the tank into the two compartments. A revolving skimmer arm carries a baffle and pivoted skimming blade which move floating solids toward a trough at the tank wall. The collected scum is carried into the trough to the scum pit.

b. Lower compartment. The digester mechanism has two revolving radial sludge-stirring arms which just clear the tank bottom and two scum-breaking arms located just below the ceiling; it has a covered gas dome for gas collection and takeoff.

c. Scum pit. The scum pit or transfer box (fig. 56) on the side of the tank is equipped with a pump. This pit may receive digester supernatant or settling-compartment scum.

d. Piping. Piping is provided to permit pump discharge to either settling or digester compartments and coils may be provided for heating the digester.

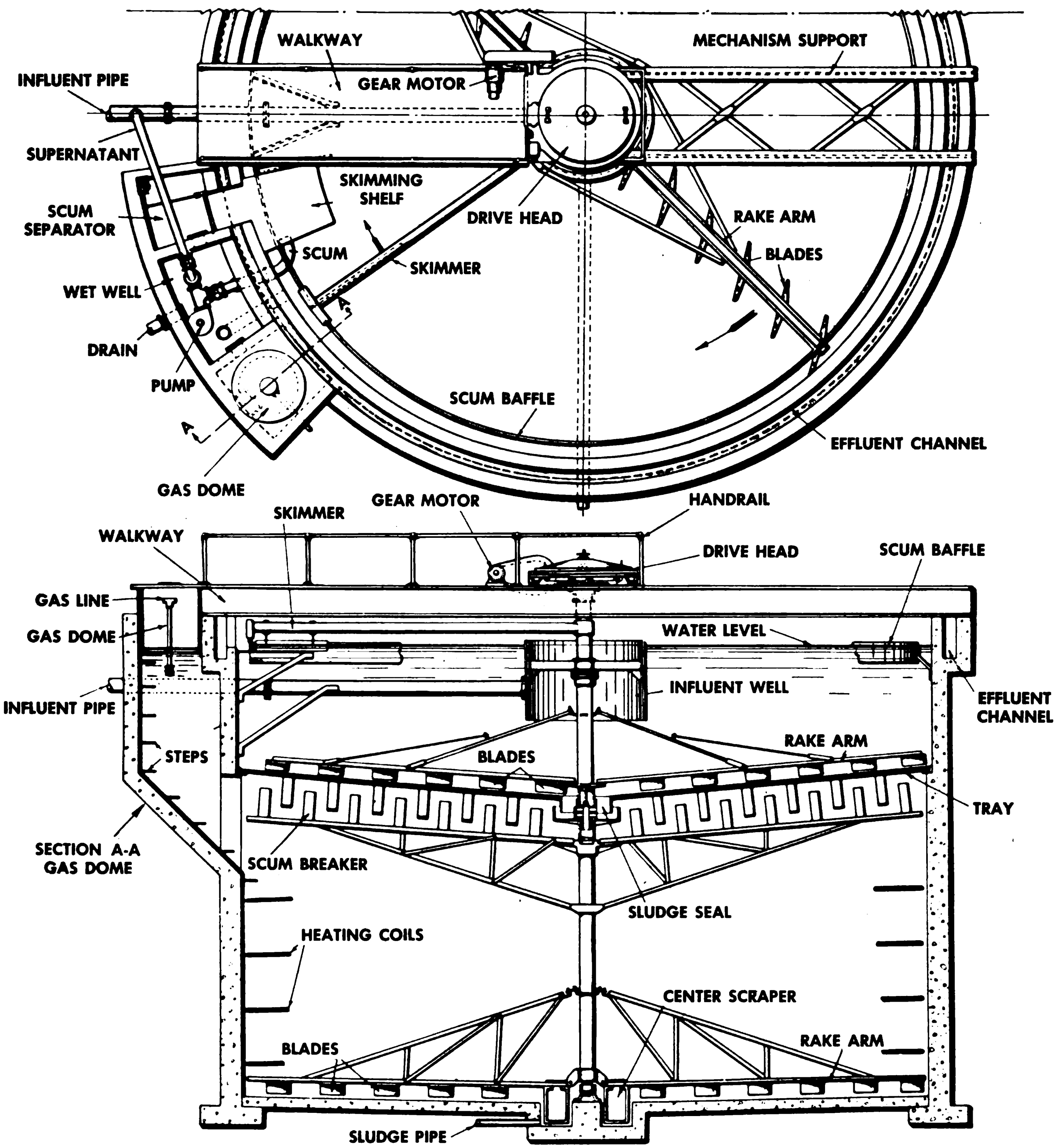


Figure 54. *Plan and section of clarigester.*

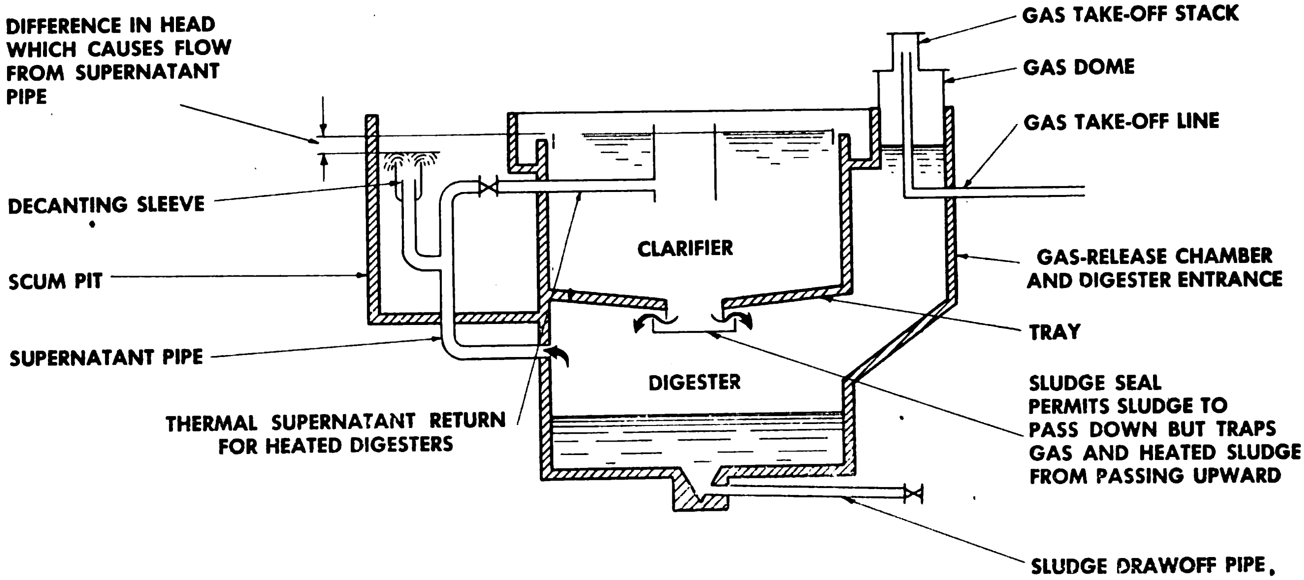


FIGURE 55. *Operation of clarigester.*

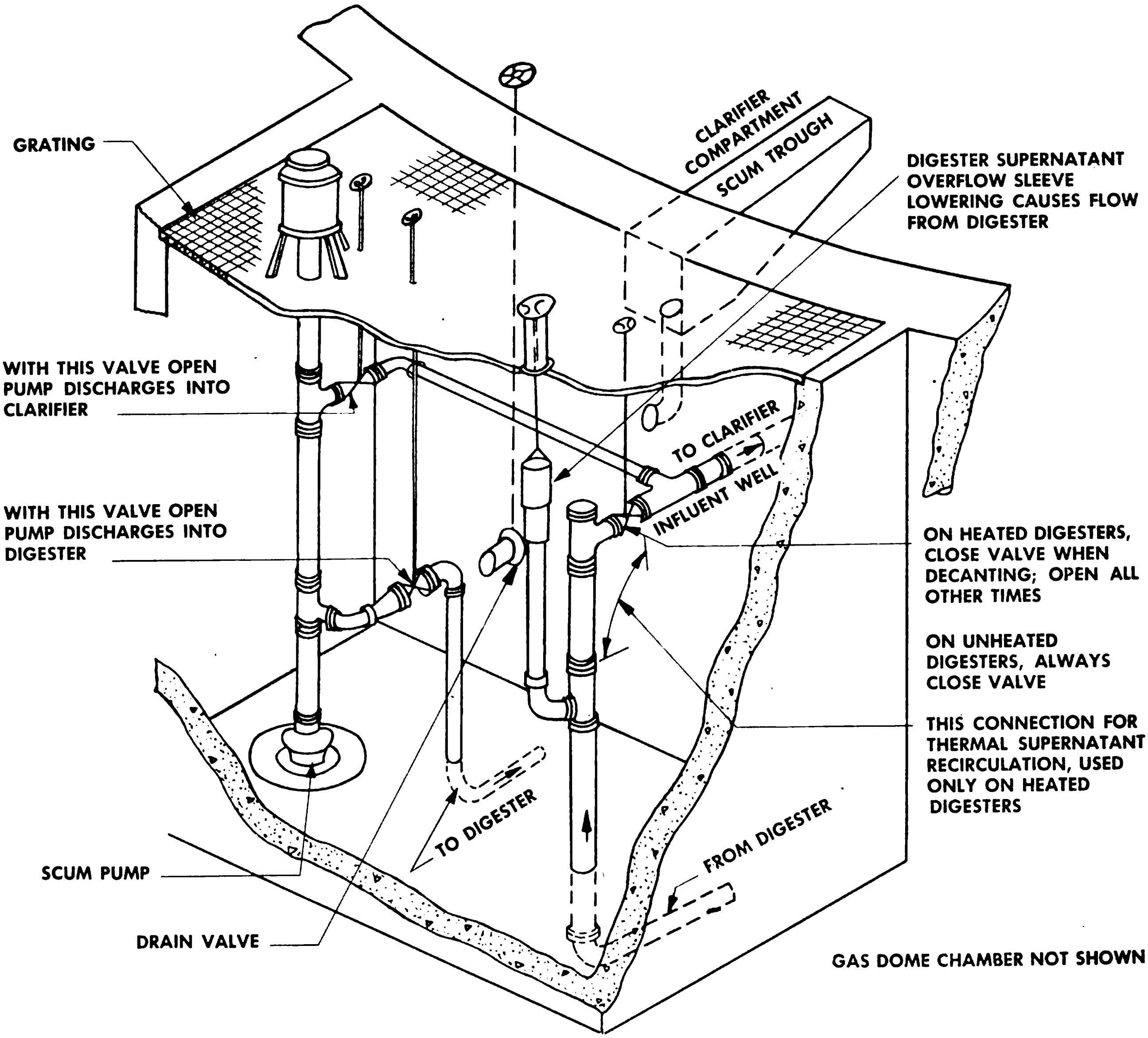


FIGURE 56. *Arrangement of scum-pit piping.*

70. Operation of Clarigester

a. Settling compartment. Except for sludge removal, the clarigester operates similarly to the circular settling tank with mechanical sludge collector. (See par. 74.) Raw sludge drops through the trapped hole in the settling-compartment floor into the digester at the same time the supernatant is removed from the digester. (See fig. 55.) If sludge appears on the settling-compartment surface, it is not transferring properly to the digester and one or more of the following corrective procedures may be followed.

(1) Withdraw more supernatant.

(2) Check to see that sludge seal is not clogged with screenings, sand, or some foreign object by shutting off the mechanism and prodding around the settling-compartment cone with long pole. In extreme cases, lower water level for actual inspection. Screenings passing through the bar screen are likely to cause blockage. Remove them regularly and carefully.

(3) Pump less scum liquid into digester compartment. High pumping rate without a compensating supernatant withdrawal forces digester contents back through the seal.

b. Scum handling (fig. 56). Scum from the settling compartment should be pumped to the digester. To keep down the quantity of water added to the digester, determine the thickness of the scum layer on top of the clearer liquor in the scum box before starting the pump. Pump the clearer liquor into the settling compartment, switching valves just as the scum load is reached to send it to the digester. Whenever the scum pit is drained, hose it down thoroughly to avoid odors. If the quantity of scum is too much for the digestion compartment, dispose of it by incineration or burial.

71. Operation of Digester Compartment

Operation of the clarigester's digester compartment is similar to the separate sludge digester described in paragraphs 80 to 87.

a. Starting operation. (1) *Heating.* Fill clarigester with sewage or water and heat contents of the digestion compartment by auxiliary boiler to about 80° F. before allowing sludge to accumulate.

(2) *Alkalinity control.* (*a*) Seed the digester if feasible. In the absence of seeding and during initial operation, add enough hydrated lime to maintain sludge pH of 7.0 to 7.4.

(*b*) Make lime slurry in a barrel for liming process. Dump slurry into scum pit and pump it into the digester.

(*c*) Flush pit and pump for a few minutes with sewage from the scum trough or settling-tank drain.

(*d*) Check pH of supernatant daily.

(*e*) Take sample for determining pH several hours after adding lime. Find proper amounts and frequency of lime additions by trial, using a 1-gallon sample of sludge and adding a known amount of the lime-slurry.

(3) *Gas production.* Because gas production does not start for several days after the initial operating period, keep gas dome off for observation. As the pH approaches 7.0 or above, gas production increases until odor and boiling action are noticed in the dome. After making sure that the gas line is clear, install gas dome. The gas line should have a moisture trap and flame arrester and is usually connected to a waste-gas burner. After the dome is fastened and air is flushed from the lines, gas at the burner should support combustion unless it is still too low in methane. In this case, check again after a day or so.

b. Supernatant overflow. Lowering the sleeve or decanting valve (fig. 55) causes fresh sludge to flow from settling to digester compartments and supernatant to flow from digester to the box.

(1) Operate supernatant overflow to maintain low sludge level in settling compartment, as explained in paragraph 74 for sludge removal from separate settling tanks. During the initial operating period until experience teaches correct practice, lower sleeve two to four times a day 15 to 30 minutes with about ½-inch flow depth over the lip. When the clarigester is operating close to capacity, operate supernatant overflow every 4 hours.

(2) Pump supernatant to the settling compartment. If the temperature difference between digester and the settling compartment is 20° F. or more, the supernatant may return to settling compartment without pumping if the valve on the supernatant return line is open. Partially close valve to cut down quantity of automatic return as desired. Close valve when pump is used or when adjustable sleeve on overflow is lowered. For unheated digester, keep valve closed; for heated digester, lower adjustable sleeve a few minutes daily and check quality of supernatant observed.

(3) If the supernatant contains much solids, sludge in the digester may have reached the draw-off level, about 4 feet below top of settling compartment

floor at side of tank. Withdraw sludge when this level is reached.

c. Scum. Open handhole in the gas dome occasionally to check for scum that should be removed. If material on top is sewage sludge instead of scum, sink it by stirring. Ladle out accumulated indigestible material such as hair, sticks, matches, bottle caps, etc. The sluice gate in the dome at the water level is used to withdraw scum into the scum pit.

d. Sludge withdrawal. After the digester operates for several months, it fills with digested sludge until an overload may be caused. Before an overload occurs, draw out some of the digested sludge.

(1) Before drawing sludge, see that it is properly digested. Properly digested sludge is granular, without unpleasant or sour odor, and normally has a volatile-solids content below 55 percent. Draw sludge when supernatant runs thick with solids, normally indicating that the sludge is within 2 or 3 feet of the tray.

(2) Draw sludge slowly onto the bed, opening the draw-off valve only slightly to prevent semi-digested sludge or liquor from funneling through. Slow withdrawal discharges any sand in the tank and prevents a drop in water level below the weir in the settling tank.

(3) Where sewage is pumped to the clarigester, keep pump operating while drawing. Always leave at least *3 feet* of sludge in the digester to seed the new sludge.

(4) Compute digester content between the supernatant take-off and the 3-foot level so amount going into sludge beds of known size can readily be determined in advance.

(5) If the scum pit has a sampling valve with piping extending down into the digester compartment, stop drawing off sludge when flow from this valve starts to run thin. Withdrawing too much sludge may upset operation so much that the digester operation acts like a newly started unit.

e. Gas hazards. Digester gas burns and when mixed with the right amount of air, it is explosive; it may also be toxic or poisonous. To insure safety at all times, observe the following rules:

(1) Post a danger sign near the gas dome.

(2) Keep all lighted cigars, pipes, cigarettes, or open fire away from the digester at all times.

(3) Do not inhale digester gas.

(4) Do not enter digester unless it is empty of all sludge and forced ventilation has cleared it of gas. Use life line with two men above. Remember that no ordinary gas mask supplies oxygen.

72. Control Tests and Records for Clarigesters

Control tests are the same as for Imhoff tank (par. 67) except that sludge depth is checked by supernatant appearance and quality rather than actual measurement. Monthly and daily records are also the same as for Imhoff tanks. (See par. 68.)

Section VII. SEPARATE SETTLING TANKS AND SLUDGE PUMPS

73. Separate Settling Tanks

Separate settling tanks or clarifiers are single-purpose structures for removing settleable solids from the sewage. Sludge deposited in these tanks is removed to a separate digestion tank or other place of disposal.

a. Types. Settling tanks classified as to purpose include primary tanks for treating raw or screened sewage, intermediate tanks located between two stages of biological treatment, and final tanks for last stage of settling. They are also classified according to method of sludge removal as hopper-bottom tanks and mechanical sludge-collection tanks. Those designed for mechanical sludge removal may be rectangular, circular, or square.

(1) *Rectangular type.* Rectangular type tanks are shown in figure 57. Figure 58 is an overhead view of this tank showing the sludge and scum-removal equipment. Chain conveyors sweep the sludge particles accumulated on the bottom toward the sludge hoppers at the influent end. On the primary tank, the conveyor sweeps the entire surface of the tank forcing the scum directly to the draw-off point in front of the effluent baffle. Sludge hoppers are emptied by gravity or by pumping while the tank remains in operation.

(2) *Circular type.* The circular type tank with mechanical sludge collection is illustrated in figure 59. Figure 60 is a cut-in view of a circular tank, showing a type of sludge collector mechanism. The influent comes through a centrally located, inverted siphon surrounded by a submerged diffuser which introduces the feed quietly well below the surface, distributing it evenly to all parts of the tank. The radial flow through the tank reaches minimum velocity at the overflow point across a continuous peripheral weir. Blades attached to rotating arms scrape the sludge from the floor of the tank to a small centrally located hopper. Sludge is removed

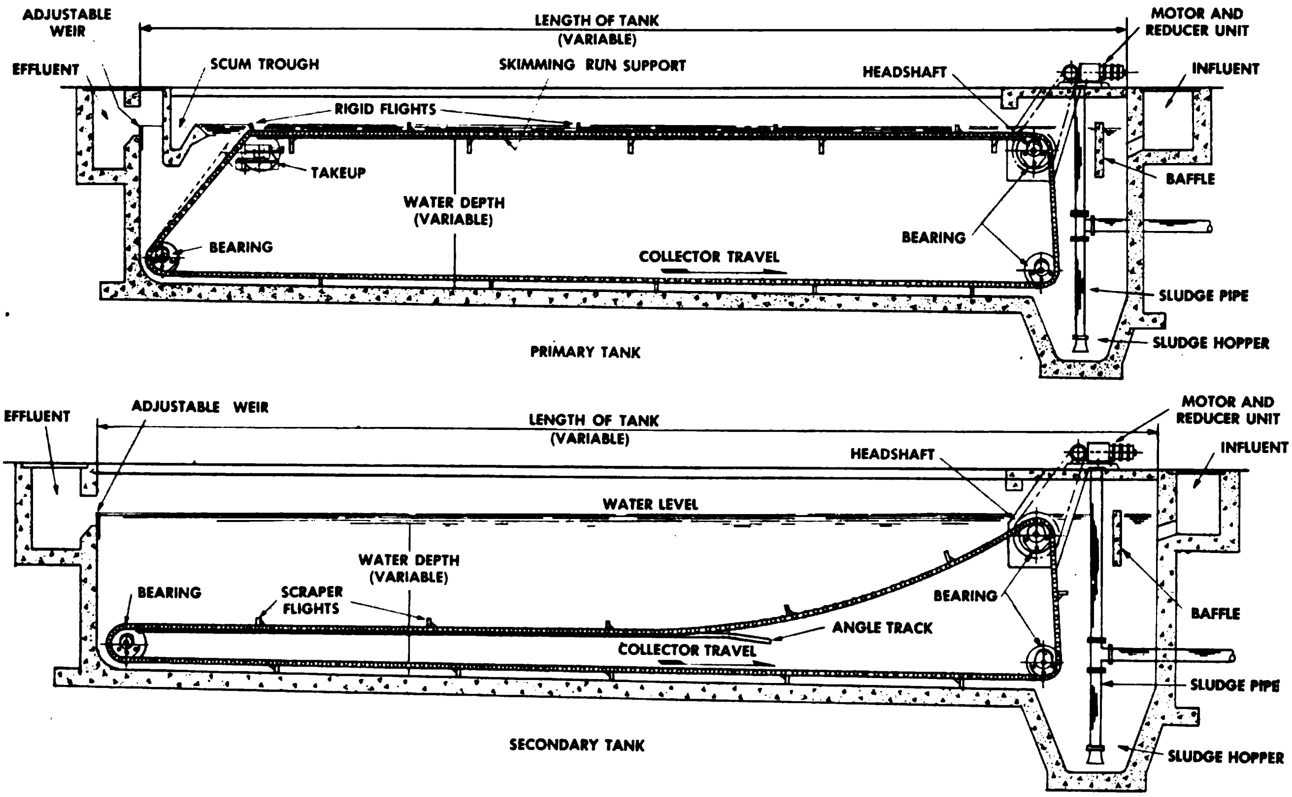


Figure 57. *Rectangular settling tanks and mechanisms.*

through a sludge pipe either by gravity or by pumping.

(3) *Hopper type.* The single conical hopper and the multiple-hopper type settling tank are illustrated in figure 61. Sludge accumulating in the hopper sections is removed through withdrawal pipes. Hoppers take the place of a sludge-collecting mechanism and are well suited to smaller installations.

b. Detention periods. The normal detention periods of primary-and secondary-settling tanks should be 2.5 hours for average daily flow, except for activated-sludge-plant primary tanks which should be 1.5 hours. Excessive detention may cause septic sewage, produce odors, and increase the load on secondary-treatment units. Where duplicate units are used, long detention periods are avoided by removing one or more tanks from service during continued low flows or by recirculating effluent from secondary units through the primary tank. When removal of solids by settling tanks is far below normal (50 to 70 percent suspended solids), the cause is determined; operators constantly look for ways to improve operation.

74. Operation

a. Cleanliness. Good housekeeping at the settling tank is essential to prevent odors, flies, and unsightly appearance. Floating solids passing out with the effluent may clog filtering equipment; grease may cause ponding of filter media.

(1) *Floating material.* Floating material must be removed once each shift or oftener if present in large quantities. Some mechanical skimmers automatically remove material to a sump for disposal; other tanks have a manually-operated skimming pipe. However, a hand skimming tool (fig. 58) should always be used to facilitate entrance of skimmings into the pipe or trough. Where skimmings are pumped to the digester, a minimum of sewage and wash water should go with it to prevent upsetting the digester operation. If large quantities of fairly dry skimmings tend to upset digestion, they should be collected in a covered can with openings for draining excess water and hauled to a sanitary fill or incinerator. The can must not be placed where drainage becomes a nuisance. If a fill is not available, skimmings are drawn to a trench and covered with at least 2 feet of earth. A spray

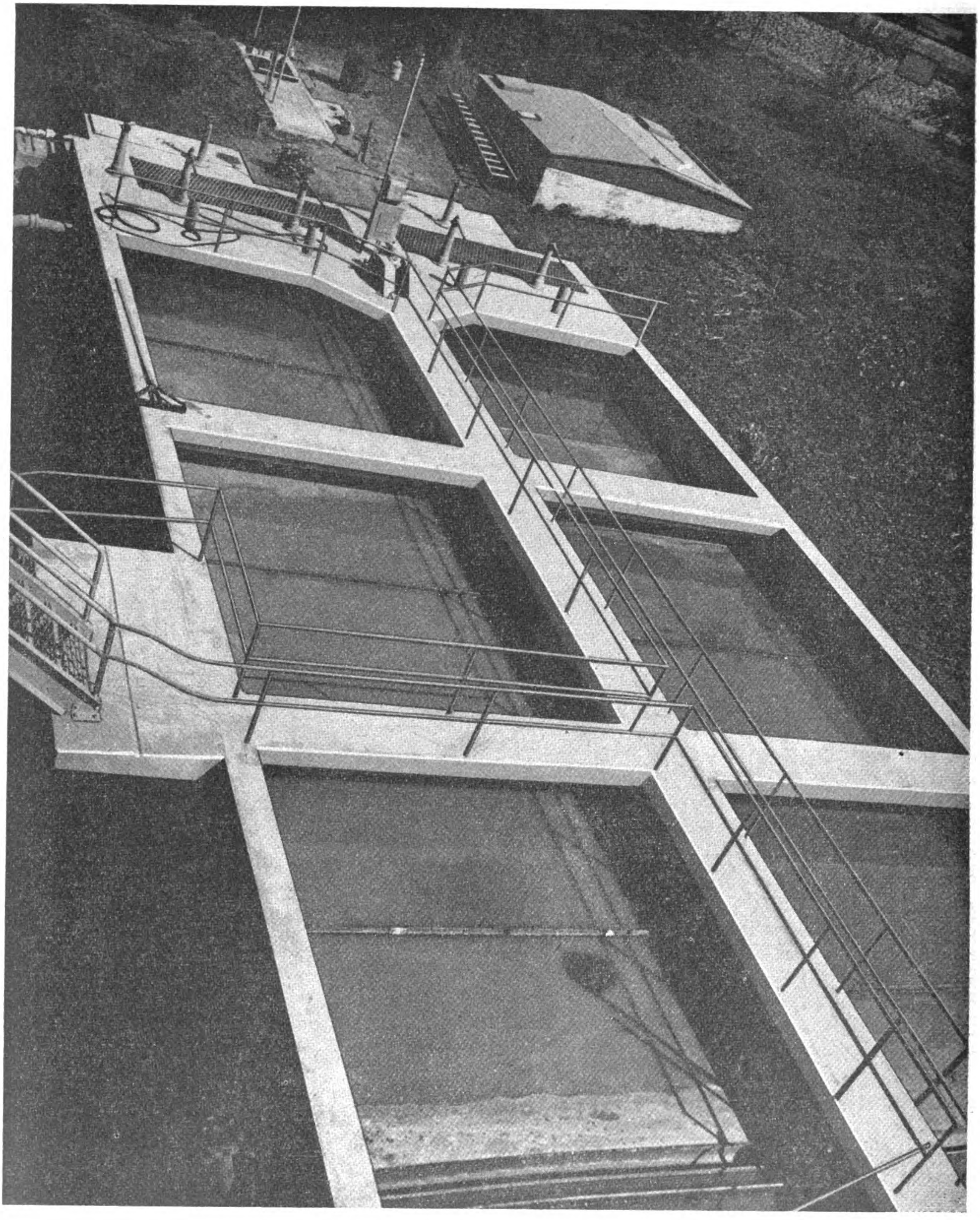


FIGURE 58. *Rectangular tanks showing skimming action of mechanism.*

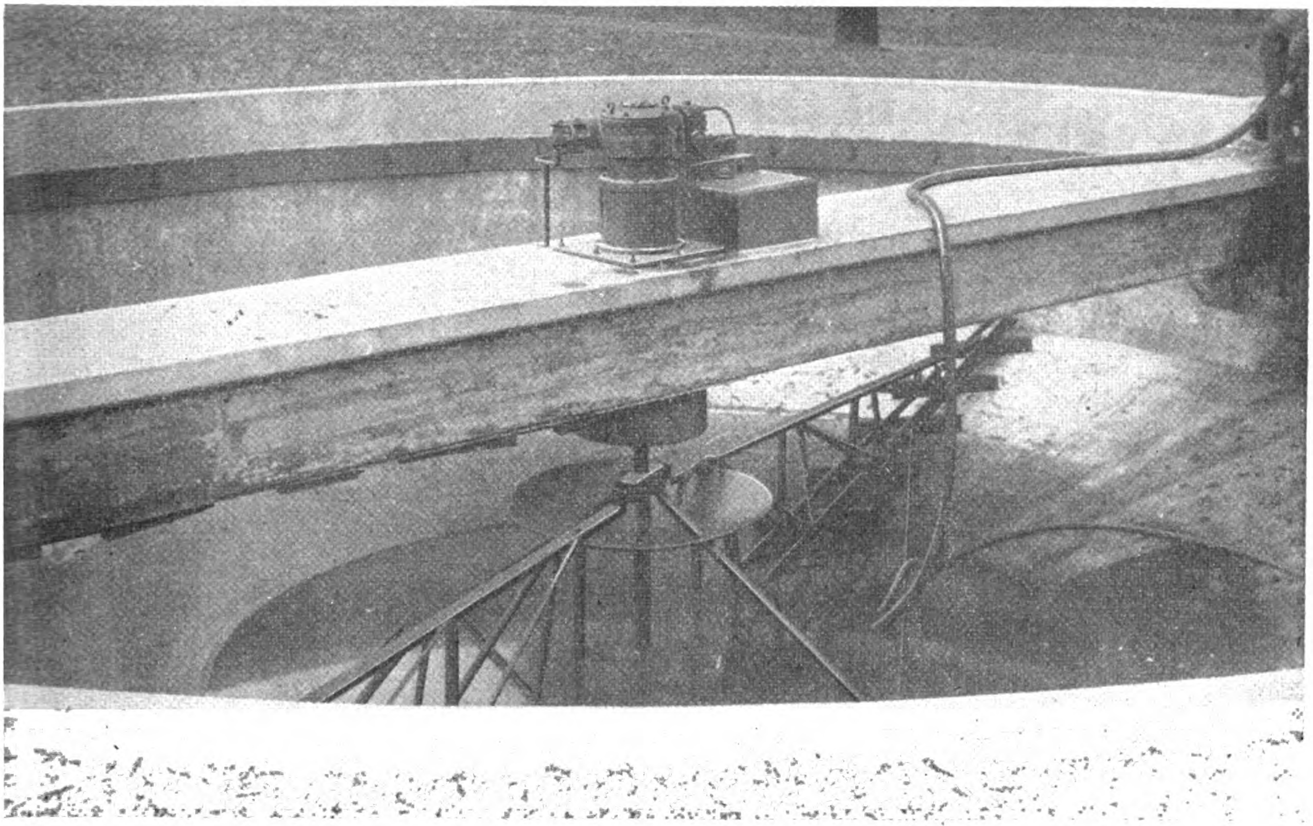


FIGURE 59. *Circular final-settling tank during cleaning operations.*

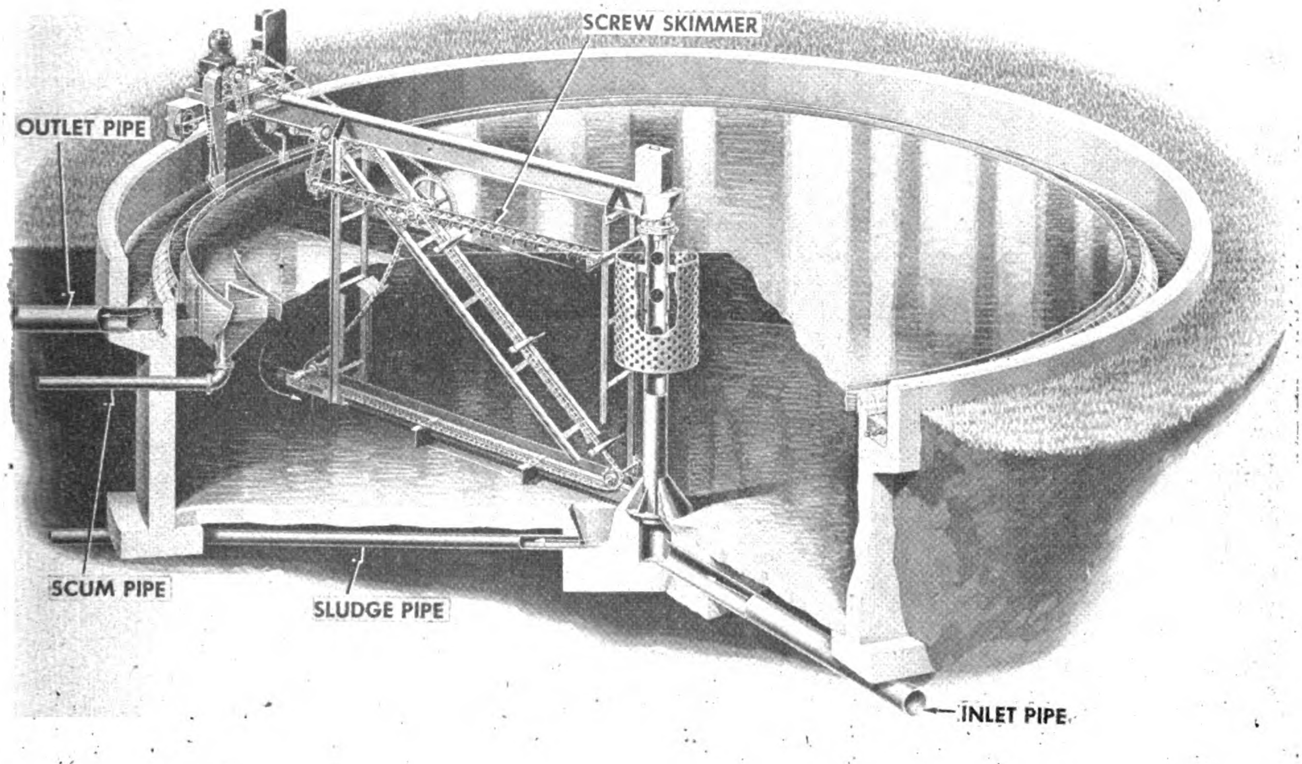


FIGURE 60. *Circular primary-settling tank.*

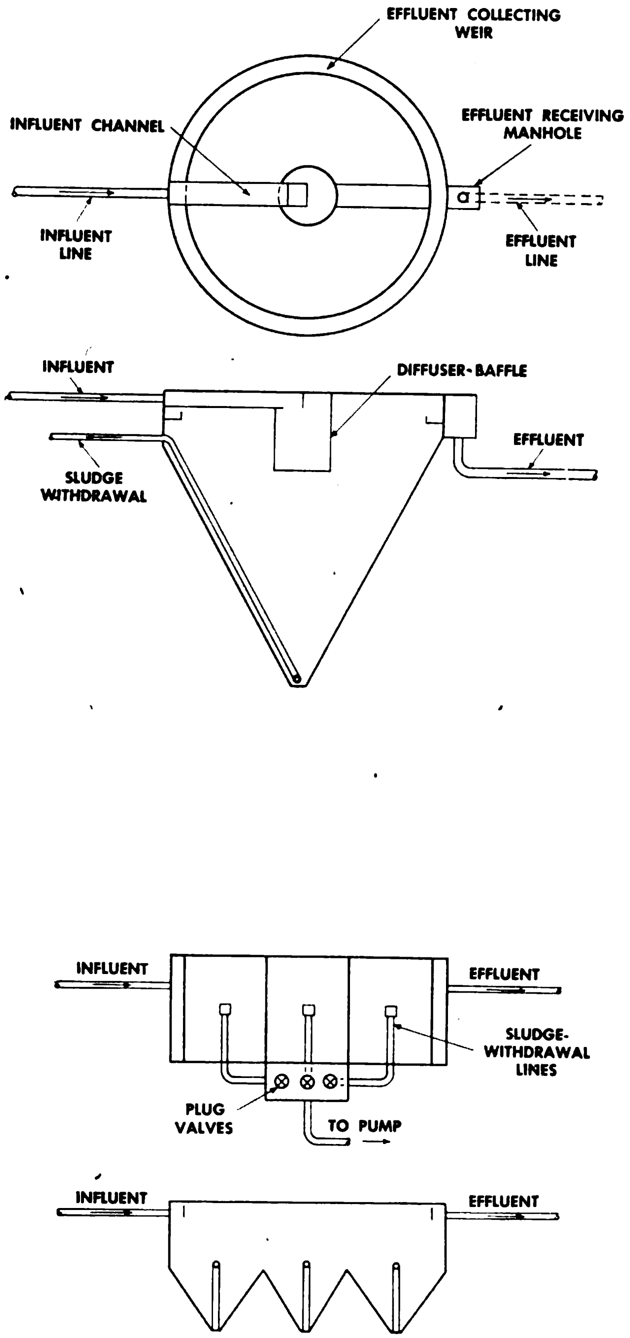


FIGURE 61. *Single- and multiple-hopper settling tanks.*

of water under pressure directed against floating material frequently settles floating material. (See fig. 62.)

(2) *Sidewalls.* (*a*) Sidewalls of channels, baffles, weirs, launders, and tanks are kept clean of grease and other solids by hosing, scraping, or brushing once each day or oftener if necessary.

(*b*) Dead ends and corners are brushed at least once each shift and fine sand and gravel are removed for burial or used as fill.

(*c*) Decks and walks are hosed at least once each day. Where pressure is not available for hosing, secondary effluent may be used with a portable pump, pressure system, or other pumping equipment.

(3) *Grit.* If grit appears in channels or hoppers, grit-chamber operation is checked. If the unit has no grit chamber, one should be installed if necessary. However, since grit is a sign of breaks in the sewer system or storm-water connections, the system should be checked thoroughly before a grit chamber is constructed.

b. SLUDGE WITHDRAWAL. Proper sludge withdrawal is important to settling efficiency. A flexible schedule of withdrawing concentrated sludge must be established with the following factors considered.

(1) *Solids content.* The sludge's solids content should be as high as possible. This means a slow rate of withdrawal and stopping withdrawal when sludge becomes thin.

(*a*) Water volume in the digester must be reduced wherever possible because this volume directly affects digester operation. A decrease in solids content causes a larger volume of sludge to be heated, a greater volume of digester supernatant to be returned, and reduction of effective capacity. *Example:* 3 pounds of dry solids pumped as a 3 percent sludge puts into the digester 97 pounds, or about 11.7 gallons of water; the same dry solids pumped as a 6 percent sludge introduces 47 pounds or about 5.65 gallons of water, about half as much. Sludge must be drawn slowly (50 to 60 gpm or less) to avoid pulling light sludge and sewage to the intake; it is sampled (par. 157) during the drawing to note the consistency and obtain the composite sample. A quick-opening 2-inch valve must be provided for sampling if other means are not available. Sludge of thin consistency can be recognized from experience by correlating its appearance with sludge-solids test results. (See par. 159.)

(*b*) Hopper-bottom tanks, especially Doten tanks used as separate settling tanks, require more care in drawing sludge because of the larger number of hoppers. Sludge from the hoppers at the effluent end normally has a low solids content, but must be removed to prevent carrying over with the effluent. Hoppers are squeegeed several times each week to remove adhering solids.

(2) *Frequency.* The interval between removals is regulated by sewage load and weather conditions. Shorter intervals are required during high flows of strong sewage and during warm weather. If

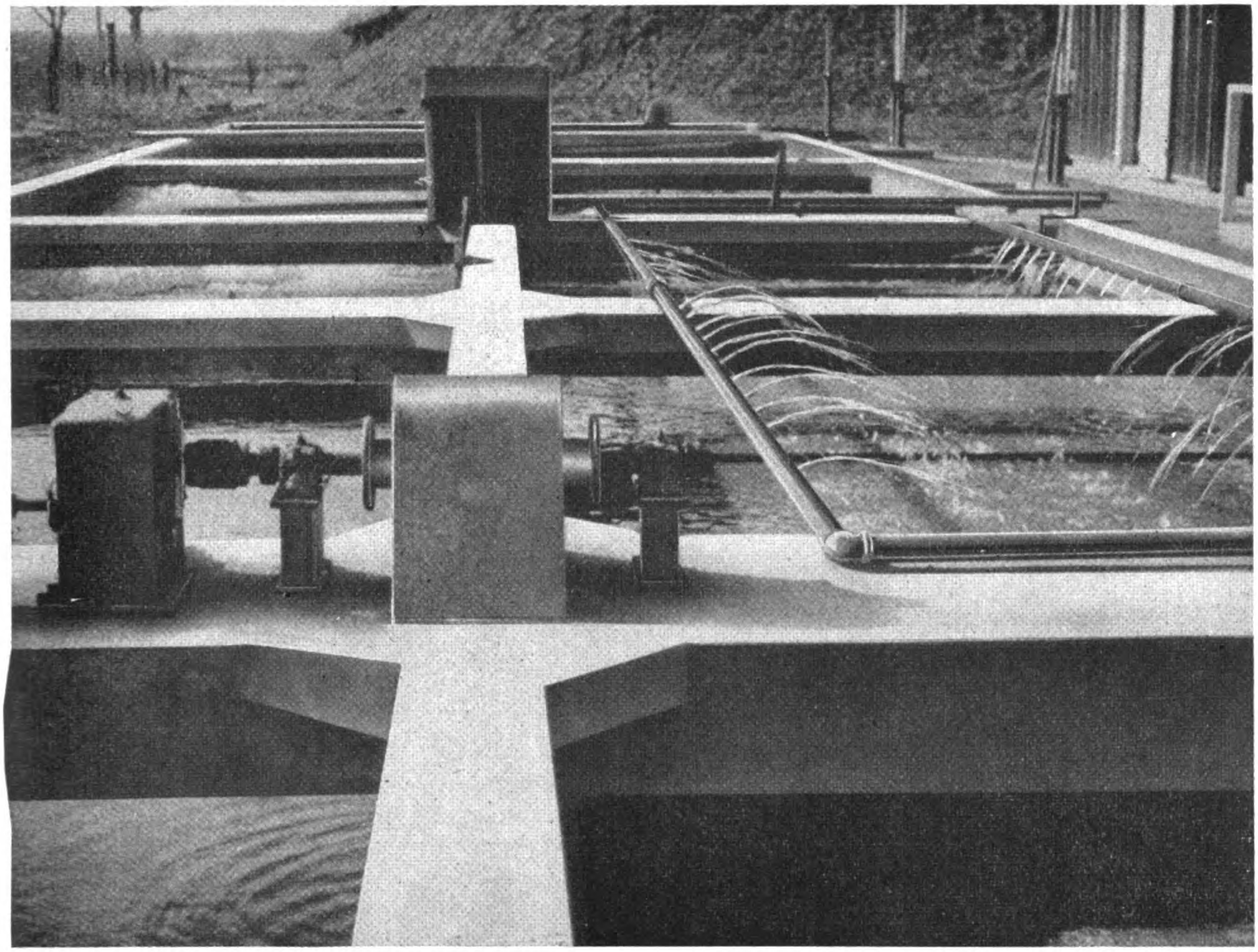


FIGURE 62. *Final-effluent spray on primary tank for settling scum.*

sludge rises from the hoppers, removal is incomplete or too infrequent.

(*a*) Primary sludge normally is removed from the settling tank three to four times each 24 hours. Sludge collected in settling tanks following standard trickling filters is drawn at least once each day, except during filter sloughing when more frequent withdrawal is advisable.

(*b*) Good judgment is necessary to obtain a balance between high solids concentration and a clean tank bottom, especially where light sludge from secondary processes is returned to the primary tank for resettling.

(3) *Mechanical collectors*. Mechanical sludge collectors in circular tanks and all settling tanks for activated sludge must be operated continuously. Intermittent operation of circular-tank mechanisms cause solids to accumulate on the tank floor, placing a large starting load on the mechanism. Continuous operation provides greater sludge compaction. Sludge collectors in rectangular tanks are not usually operated continuously although it may be done, especially when the sewage is strong and the rate of flow high. The mechanism should normally be started from 1 to 2 hours before pumping, tank length governing length of this period somewhat. At least two complete runs for the length of the tank is desirable. The tank bottom must be well cleaned and old sludge completely removed to the hoppers. Rising gas bubbles and sludge along the tank indicate incomplete cleaning or too long a period between operation. Hoppers in rectangular tanks should not be filled more than 6 inches from the top. In withdrawing sludge, 2 feet of sludge blanket may be left in the hopper. Where there are two or more hoppers, only one should be drawn at a time.

c. SLUDGE VOLUME. The daily volume of sludge removed is measured by the following methods:

(1) Where sludge is drawn to an open sump before pumping to the digester, calculate volume of the sump per foot of depth. Measure depth of

sludge in the sump by calibrating a rod in reverse so the measurement may be made from the top of the sump to the surface of the sludge.

(2) Where sludge is pumped directly from the clarifier, estimate volume by minutes of pump operation multiplied by actual gallons per minute output. This requires calibration of the pumps. If reciprocating pump valves clog, time while clogged is not included.

(3) Where floating covers are installed in digesters, check volume of sludge pumped in several days against the above calculation by the rise of the cover. This procedure is one way to calibrate the sludge pump.

75. Methods of Control

a. Suspended- and settleable-solids tests are primary measures of efficiency since solids removal is a primary function. Proper operation should remove 90 percent of settleable solids and 50 to 70 percent of suspended solids. Low solids removal may be caused by short circuits in the tank, incomplete removal of sludge, incomplete collection of sludge from tank floor, short detention period causing high velocities, or long detention periods allowing gas formation in tank.

b. BOD removal is a secondary measure of tank efficiency. Low BOD removal with normal suspended-solids removal usually indicates septic action caused by an excessive detention period or incomplete sludge removal. Also indicative of these conditions is a pH value of the tank effluent lower than that of the influent.

c. Analysis of sludge samples for solids content, sampling the tank bottom for presence of solids and appearance of rising gas or sludge indicates whether or not the methods of removal are effective.

d. Causes of low efficiencies are determined and corrected; continued difficulty is reported to higher authority for advice and correction.

76. Records and Reports

a. Monthly. The following data is reported monthly:

(1) For influent and effluent of tank, settleable solids, pH, suspended solids, and BOD.

(2) For primary-tank sludge, volume removed, pH, percent solids, percent volatile matter.

(3) Change in number of tanks in operation.

b. Daily. In addition to the data required for monthly data, the following daily records are kept:

(1) Volume of sludge returned or recirculated to raw sewage or other plant units (refers generally to secondary sludge).

(2) Volume and disposition of skimmings.

(3) Remarks on operating difficulties.

77. Sludge Pumps

Reciprocating pumps (fig. 63) or pumps with cutting edges in the suction inlet (fig. 64) are most commonly used for primary sludge. Final sludges are handled by plain centrifugal pumps.

a. Reciprocating pumps. Reciprocating pumps are usually one- or two-plunger types with rubber-ball check valves on both suction and discharge.

(1) *Valves.* A plunger pump may be damaged if operated against closed valves in the pipe line, especially in the discharge line. The pump must be shut down to change valve settings when installed to pump from two sources or to deliver to separate points at different times. Otherwise, all suction-line valves or all discharge-line valves may be closed for a few seconds causing pump breakage.

(2) *Capacity.* Capacities of reciprocating pumps are adjusted by varying the stroke length, removing and replacing the shear pin after changing the position of the eccentric with respect to eccentric flanges. (See fig. 63.)

(3) *Obstructions.* Sticks, matches, and rags often clog the ball check valves, preventing operation. A pressure gauge should be placed on the discharge side of the pump. Failure of the gauge to fluctuate indicates the inlet valve is being held open; fluctuation beyond normal range indicates that the outlet valve is not seating. Valve obstructions are removed immediately through the quick-opening hand holes.

(4) *Noises.* Close attention should be given to the sound of the pump; occasionally the piping arrangement and head conditions cause noticeable water hammer when the pump is operating. This noise is loudest when pumping water or very thin sludge and decreases for heavy sludge; it can be eliminated by keeping the discharge air chamber full at all times. Some installations require air chambers on the suction side. They should be approximately 6 inches in diameter and 36 inches high.

b. Cleanliness. All parts of pump, pump-room floor, and sampling arrangements are kept clean at all times. Maintenance instructions given in TM 5-666 must be followed.

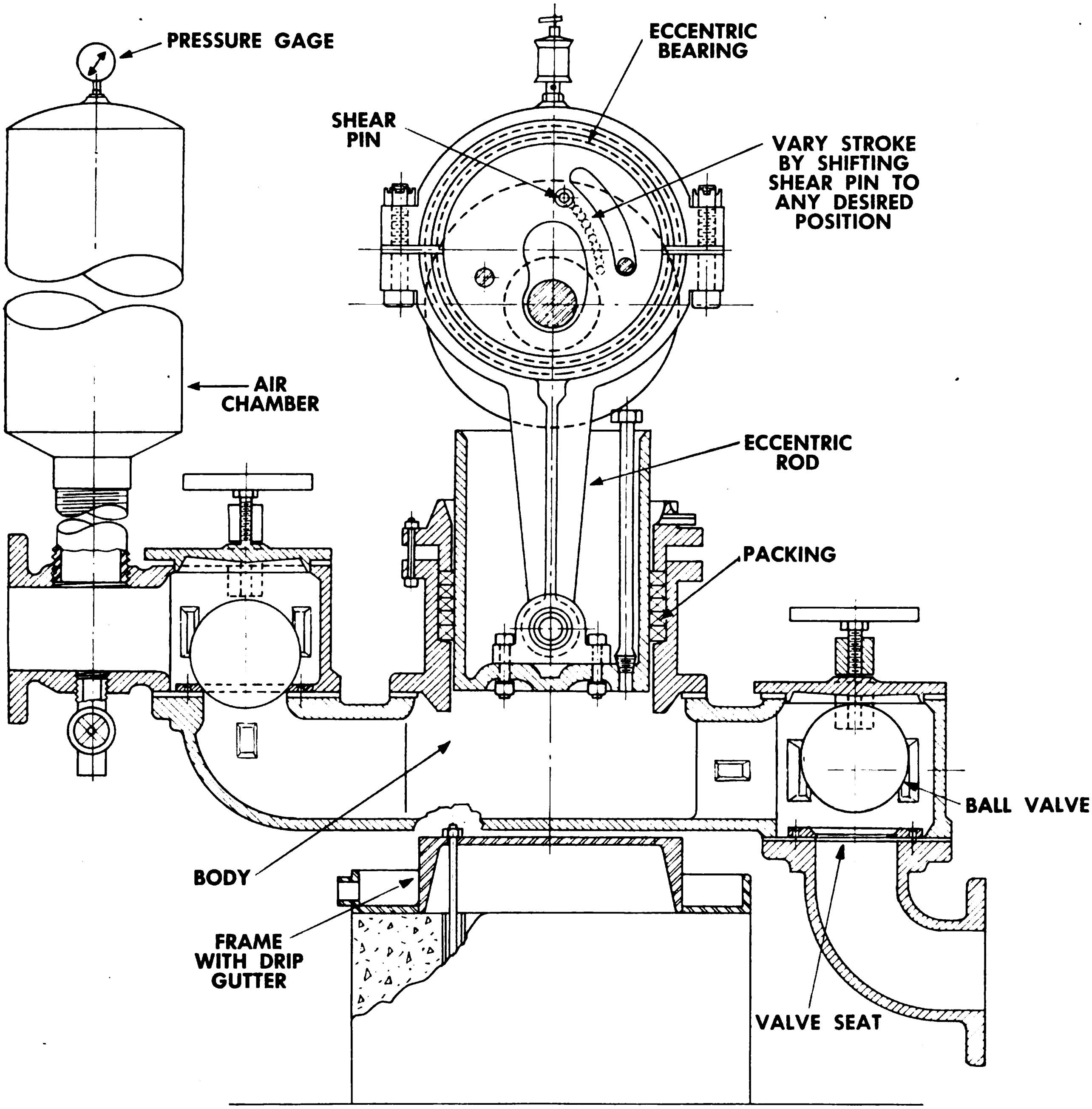


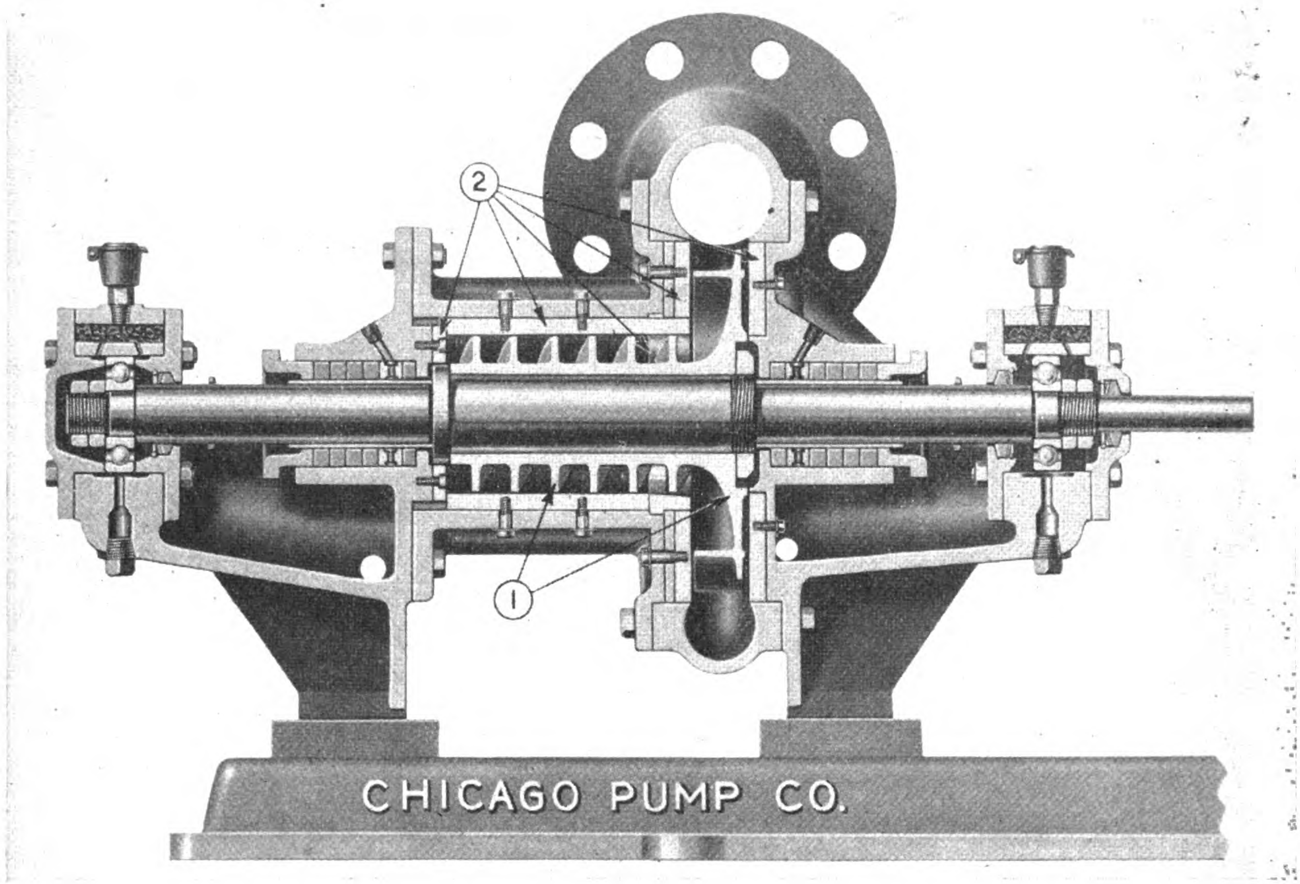
FIGURE 63. *Section of reciprocating pump for sludge.*

c. SAMPLES. The method of collecting sludge samples is described in paragraph 157.

Section VIII. DIGESTERS AND GAS EQUIPMENT

78. Sludge Digestion

a. GENERAL. The sludge collected in settling tanks is usually treated in a separate sludge digester unless it is returned to the sewage flow. This unit changes the sludge into readily disposable products with minimum interference with other plant operation. Organic matter in the sludge furnishes food for bacteria which break it down into simple, more stable substances by anaerobic decomposition. The final products of the digestion are more or less stable, humuslike solid matter (digested sludge); sludge liquor, including liquefied and finely divided solid matter (supernatant liquor); and gases. The digested sludge must be put on drying beds (par. 103); the supernatant liquor is usually returned



① Stellite cutting worm and impeller. ② Stellite shear plates.

FIGURE 64. *Scru-peller pump for sludge.*

to the plant influent; and the gas is burned as waste or fuel. The digestion process has three stages:

(1) A highly acid stage marked by a lowered pH and production of gas with high carbon dioxide and some hydrogen sulfide content.

(2) A less acid stage accompanied by a rising pH to about 6.8, production of ammonia compounds, and lessened gas output. This gas contains some hydrogen as well as carbon dioxide and methane.

(3) An alkaline fermentation stage in which the pH may rise, large volumes of gas of high methane content are produced, and the sludge acquires a tarry odor. During this stage, the pH does not vary with relatively large additions of acid or alkaline material and agents of fermentation (enzymes) accumulate.

b. MERGING OF STAGES. The first two stages occur during the starting period of the digester. After the third stage is established, fresh sludge may be added without appreciably affecting the characteristics of the tank contents. The three stages gradually merge until little evidence of the acid stages remains. Rapid digestion follows with heavy evolution of gas with high methane content.

c. EFFECT OF HEAT. Temperature determines the rate of digestion. Mesophilic digestion, which progresses best between 90° and 100° F., is generally used. Above 105° F., the organisms of mesophilic digestion become inactive and thermophilic digestion occurs. The latter range is not presently used because of the odors and operating difficulties. Approximate time of digestion of different temperatures can be determined from figure 65. Between 90° and 100° F., well-digested sludge is produced in about 24 days. At 85° F., 90 percent of digestion is completed in 26 days, at 75° F., 35 days, and at 55° F., 55 days. High temperatures are more difficult to maintain and require considerable heat transfer, especially in the cold climates. The *practical* operating range is between 85° and 95° F.

d. MIXING. Good mixing of fresh sludge with seeding material (digesting sludge) is essential to optimum operation. Considerable mixing is done naturally by the rising gas; in some digesters, additional mixing is done by mechanical stirrers or recirculation by pumps.

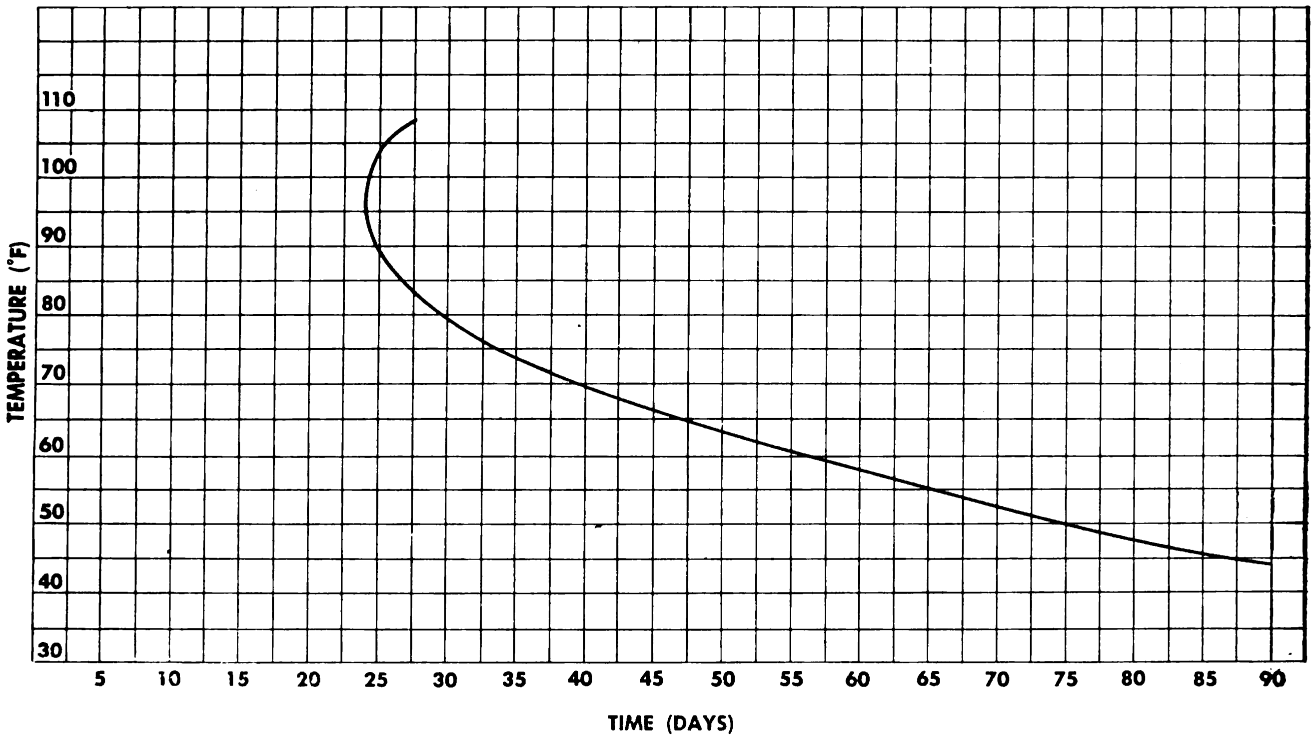


FIGURE 65. *Time required for digestion of sewage solids at different temperatures.*

79. Types of Digesters

a. CAPACITY. Most digestion tanks have the capacity to provide adequate digestion time plus additional time for storage until disposal facilities are available. The following table shows the digester capacities normally provided for Army installations.

	Digestion-tank capacity in cubic feet per capita	
	Heated tanks	*Unheated tanks*
Primary treatment only	2.0	3.0
All other plants (except activated sludge)	3.0	4.5
Activated sludge	4.0	6.0

b. TYPES. Digestion tanks are classified according to their construction or their operation. All of them have a sludge inlet at the side or top, digested-sludge withdrawal line, and supernatant withdrawal at one or more levels.

(1) *Types of construction.* (*a*) *Uncovered tanks.* Uncovered tanks are usually hopper-bottom tanks without gas-collection or heating equipment. They are used on small units or for storing partly or fully digested sludge from other digesters.

(*b*) *Fixed-cover tanks.* Tanks with fixed covers are usually concrete structures with sloping bottoms and a permanently fixed cover. The cover may be a flat concrete slab with or without space for gas above the liquid level or have dome of concrete (fig. 66) or steel (fig. 68) with space for gas. They may or may not have mixing, scum-breaking, or heating facilities. A gas dome and seal, normally in the center of the cover, are connected to a boiler or/and waste burner. Heating facilities are hot-water coils attached to the tank's walls or suspended from the roof.

(*c*) *Floating-cover tanks* (fig. 67.) Tanks with floating covers are similar to the fixed-cover type except that the cover floats on the tank's contents. This cover has several radial trusses with a watertight, steel ceiling plate attached to the bottom chords. The outer ends of the trusses are joined by a vertical rim plate a few inches inside the tank wall. The rim plate extends far enough above the ceiling plate to provide enough buoyancy to float the cover. The floating cover keeps scum submerged. The gas dome is placed at the center of the cover.

(*d*) *Gas-holder covers.* Steel gas-holder covers (fig. 68) are supported by gas pressure. A deep skirt extending into the liquid provides a gas seal around the edge, the cover rising and falling with varying gas volume in storage. The center column and guides at the outside edge prevent cover from tipping. Liquid level and cover may be lowered about 5 feet during sludge withdrawal, but tank is normally operated at maximum liquid level.

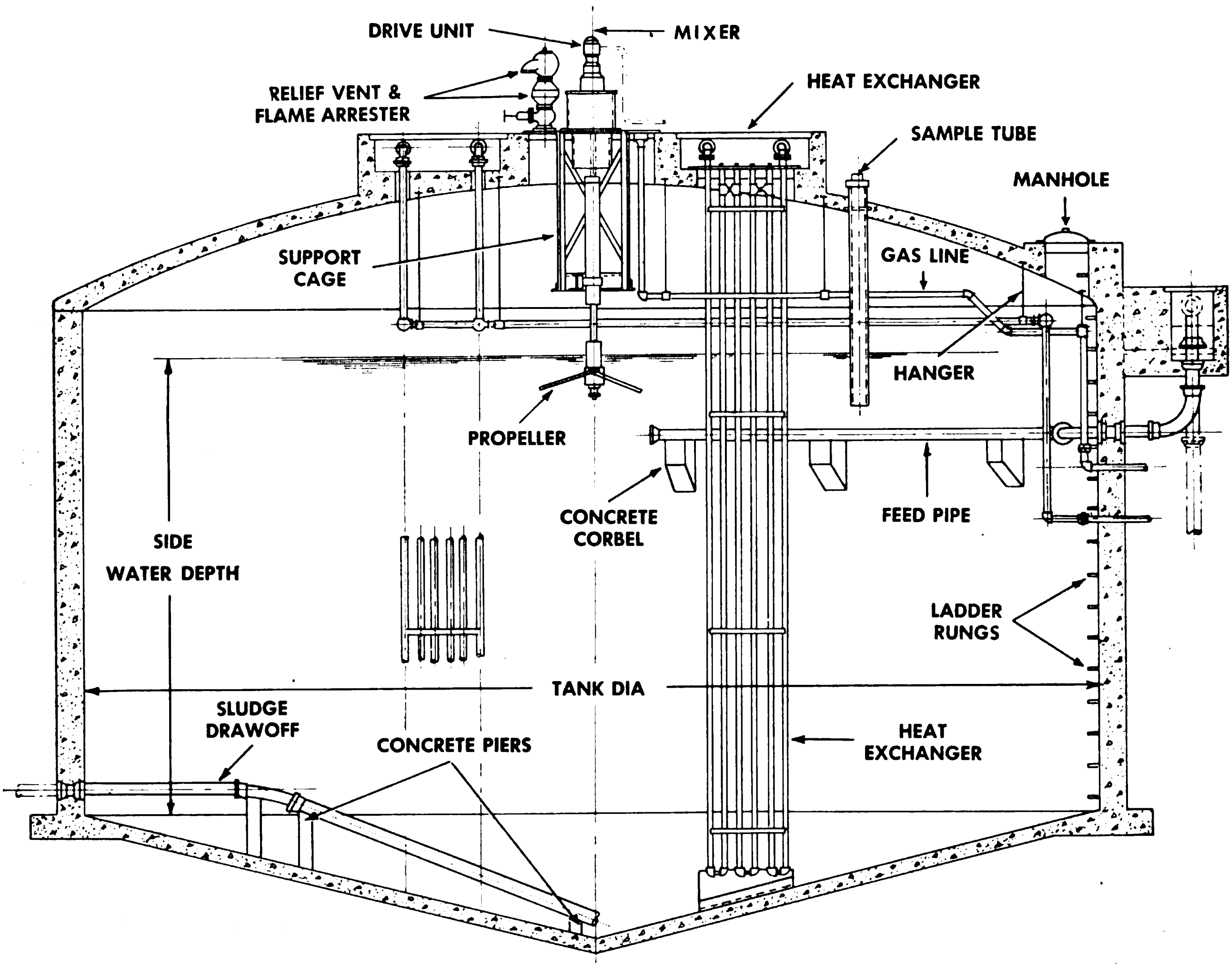


FIGURE 66. *Digester with fixed cover.*

(2) *Types of operation.* (*a*) *Two stage.* Two or more tanks provide flexibility of operation. They can be operated independently, as single-stage digesters in parallel, or as two-stage digesters in series with one tank a primary and the other a secondary unit. Two-stage installations are frequently designed with a fixed-cover heated primary tank and a heated or unheated secondary tank with gas holder. (See fig. 68.) Gas from both tanks is collected in the secondary tank, whose cover provides storage and maintains gas pressure. Another type of installation permits either parallel or stage operation with each tank having heating facilities and floating cover. Digesters are usually made of concrete.

(*b*) *Two story.* A two-story digester for two-stage operation is shown in figure 69. This unit has a primary-stage compartment in the upper portion and a secondary stage in the lower with sludge passing to the lower compartment through transfer lines. The upper portion is heated; supernatant and gas may be withdrawn from either compartment.

80. Starting Operation

Before tanks are put in service, they should be carefully inspected, all debris removed, valves and stirring mechanism checked for proper operation, pressure-vacuum relief on covers adjusted, and all piping made tight and cleared of obstructions. Fixed-cover digesters must be completely filled with raw sewage or water to eliminate the air accumulated below the cover. The handhole in the gas dome of floating covers should be opened and the tank filled enough to lift the cover from the landing brackets or low-level supports. Open tanks should be filled only as the sludge accumulates.

a. SEEDING. Seeding with partially or well-digested sludge should be done wherever feasible.

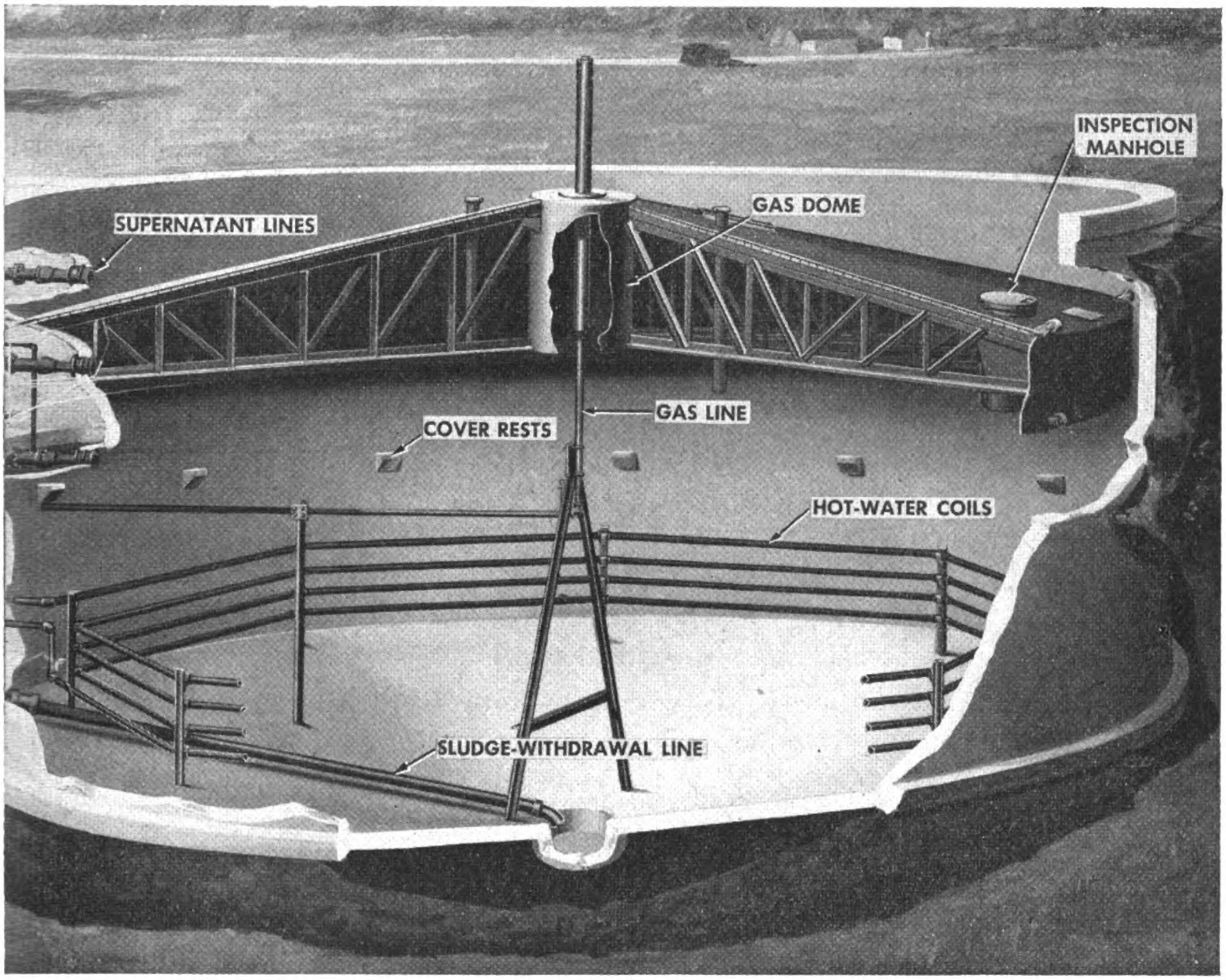


FIGURE 67. *Digester with floating cover.*

Sludge from septic tanks, Imhoff tanks, or other digesters may be transferred directly to the digester. The optimum quantity of well-digested seed is approximately 20 times the weight of dry solids as the anticipated daily production of raw sludge, but transferring such a large quantity of seeding material is impracticable unless it is readily available.

b. HEATED TANKS. Tank contents of heated digesters should be brought to between 85 and 95° F. During initial operation, not enough digester gas is produced to heat the contents. Where digesters are started in cold weather, auxiliary fuels, such as domestic or butane gas (bottled), should be used temporarily until enough digester gas is available. A temporary gas connection and adjustment or replacement of gas-burner orifices may be necessary. Auxiliary boilers for burning oil or coal are often installed as regular equipment; a portable steam boiler may be used.

c. UNHEATED TANKS. Unheated tanks started in cold winter weather may be helped by adding lime. Daily pH determinations are made. When the pH falls to 6.5, lime is added to bring it to 6.8. The quantity of lime needed is best determined by adding small known amounts of lime slurry to 1 gallon of sludge until the proper pH is reached. Lime made into a thin supension is fed into the digester at a slow rate together with raw sludge.

d. GREASE. Grease from skimmings is not transferred to the digester until digestion reaches normal operation.

81. Sludge Addition

Sludge should be drawn to the digester in fixed-cover tanks at frequent intervals and low rates to minimize disturbing the supernatant which is discharged at the same rate and quantity as the sludge

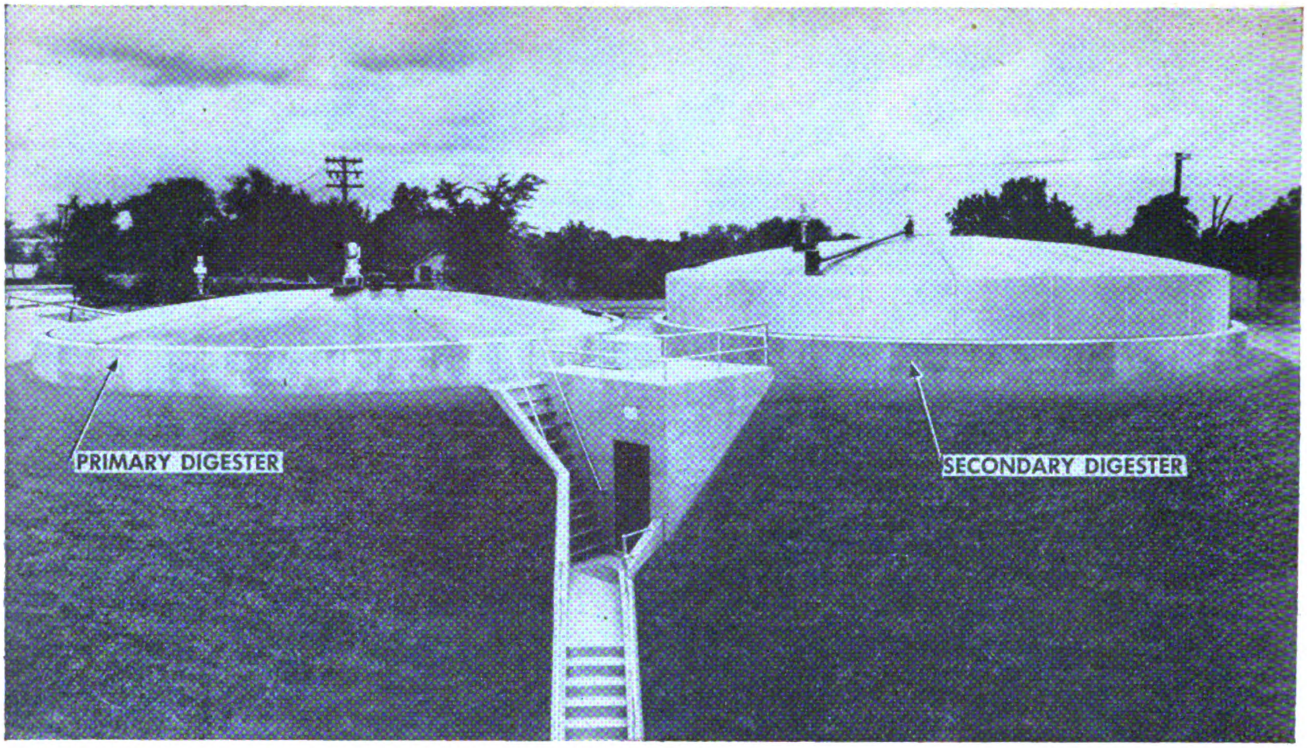


FIGURE 68. *Two-stage digesters with fixed-cover primary digester and secondary digester with gas-holder cover.*

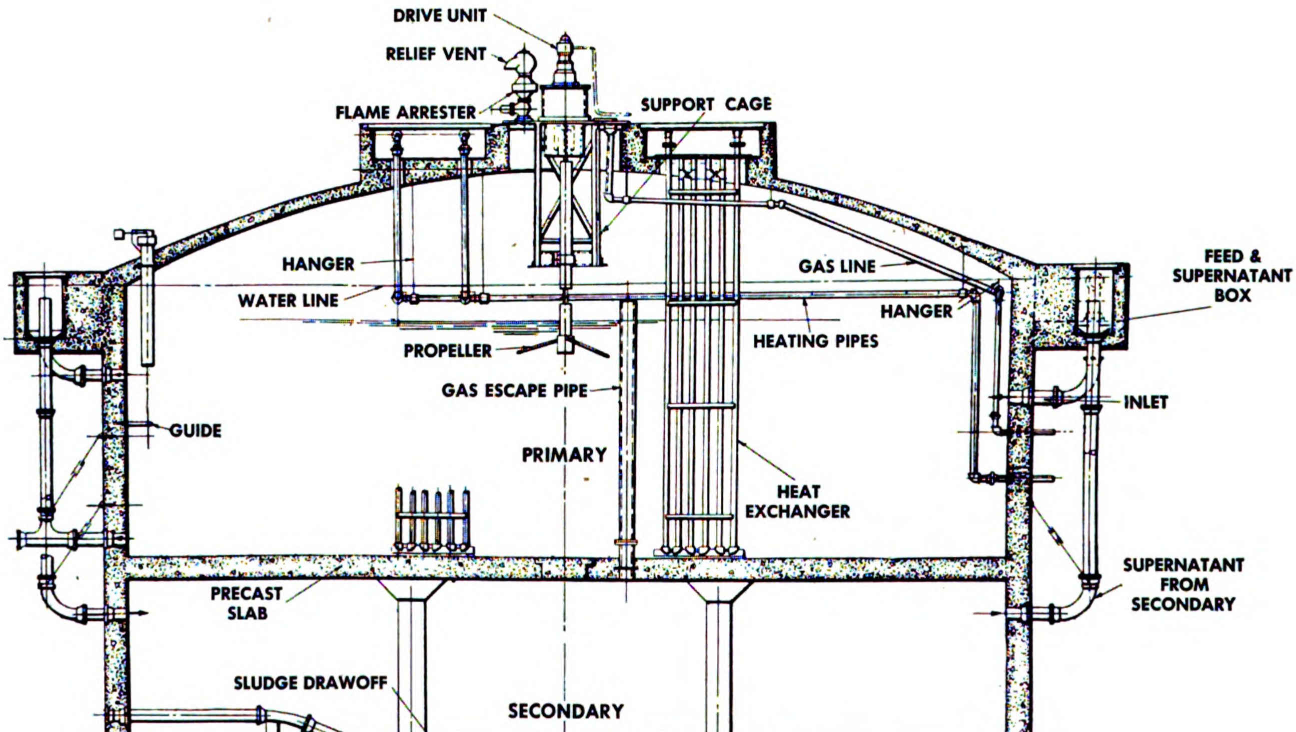


FIGURE 69. *Two-story digester.*

added. With floating-cover tanks, raw sludge additions may be less frequent because the supernatant is not necessarily drawn off at the same time. Raw-sludge drawing is regulated largely by the requirements of the settling units as discussed in paragraph 74. Where two or more digesters are operated in parallel, flow may be divided between the tanks in proportion to their size or alternated between tanks daily.

82. Withdrawal and Disposal of Supernatant

a. Withdrawal. Excessive digesting solids in supernatant returned to the raw sewage cause rising sludge in primary settling tanks and impair secondary treatment. Withdrawal is regulated to obtain supernatant with lowest possible solids content (0.4 to 0.7 percent); it is done slowly, preferably during low flow periods. Solids content is observed at each draw-off level daily and the clearest level is selected for supernatant withdrawal.

(1) *Fixed-cover digesters* (fig. 70). Addition of raw sludge to fixed-cover digesters causes simultaneous overflow of supernatant at the same rate after the initial liquid level rise. Limited control of withdrawal rate is obtained by pumping sludge for short periods at frequent intervals to cause an almost continuous, slow discharge of supernatant, or by removing an overflow ring at desired time to lower liquid level several inches. Ring must be replaced when pumping sludge.

Caution: Supernatant outlet must be kept free. If clogged, sludge pumping can raise or crack digester cover.

(2) *Floating-cover digester* (fig. 71). Supernatant is withdrawn slowly, beginning 1 to 2 hours after addition of raw sludge. If two tanks are operated in parallel and sludge pumped to each on alternate days, supernatant is withdrawn during next day.

(3) *Two-stage digestion.* See paragraph 88 for supernatant withdrawal for two-stage digestion.

(4) *Supernatant selector.* A well screen or supernatant selector mounted vertically in the digester removes supernatant from the clearest layer because heavy sludge or scum blocks the screen. Periodic backwashing with water under pressure is required; frequency depends on clarity of supernatant and degree of sludge digestion. Since excessive grease in digester plugs the screen rapidly, scum is disposed of by incineration or burial instead of pumping to digester.

b. Supernatant treatment. Suspended-solids content of supernatant is reduced by aeration, with or without adding lime, to remove dissolved gases. After settling in a small tank in batches, solids are returned to the digester and clear liquid to the raw sewage.

c. Supernatant disposal. Supernatant is returned to the raw sewage at a point where it may be equally divided between primary tanks. A submerged outlet to raw sewage eliminates odors. The strength of supernatant which can be returned to the raw sewage without decreasing treatment efficiency is determined by local experience. Supernatant with a higher solids strength is treated before return if facilities are available, discharged to a sludge bed if capacity is available, or discharged to a lagoon. When the supernatant is discharged to the surface of underdrained-sand sludge-drying beds, as little area as possible should be used. After such use in discontinued, dried scum on the bed should be removed and the sand surface broken, usually not more than 1 inch deep, by rake or hand harrow. Lagooned supernatant may be allowed to fill the lagoon, which must then be taken out of service and rested until digestion is completed and a top liquor of low solids content obtained. The lagoon site should be carefully selected because odors develop.

83. Digested-sludge Withdrawal

a. The type of tank, disposal facilities, and season of year govern digested-sludge withdrawal. Enough digested sludge is left in the tank to seed incoming raw sewage and maintain balanced, alkaline fermentation. The amount of digested sludge kept in heated, controlled-temperature tanks depends on the efficiency of the sludge-drying or disposal facilities. These tanks may be used to store digested sludge when the season of the year makes proper sludge disposal impossible. The digested sludge in the tank must be reduced to a minimum before the cold or wet season. For unheated tanks located where their temperature falls below 75° F., the season affects both digestion and sludge disposal. During the warm season, they operate similarly to the heated digester; during cold weather at least twice as much digested sludge must be kept in the tank to maintain alkaline digestion. Enough digested sludge must be left in these tanks before cold weather comes. For tanks operated in the recommended temperature range, the digested sludge should be at least 20 times the weight of volatile solids in the daily charge of raw sludge.

b. At normal operation, at least 4 feet of digested sludge above the hopper is needed to provide the

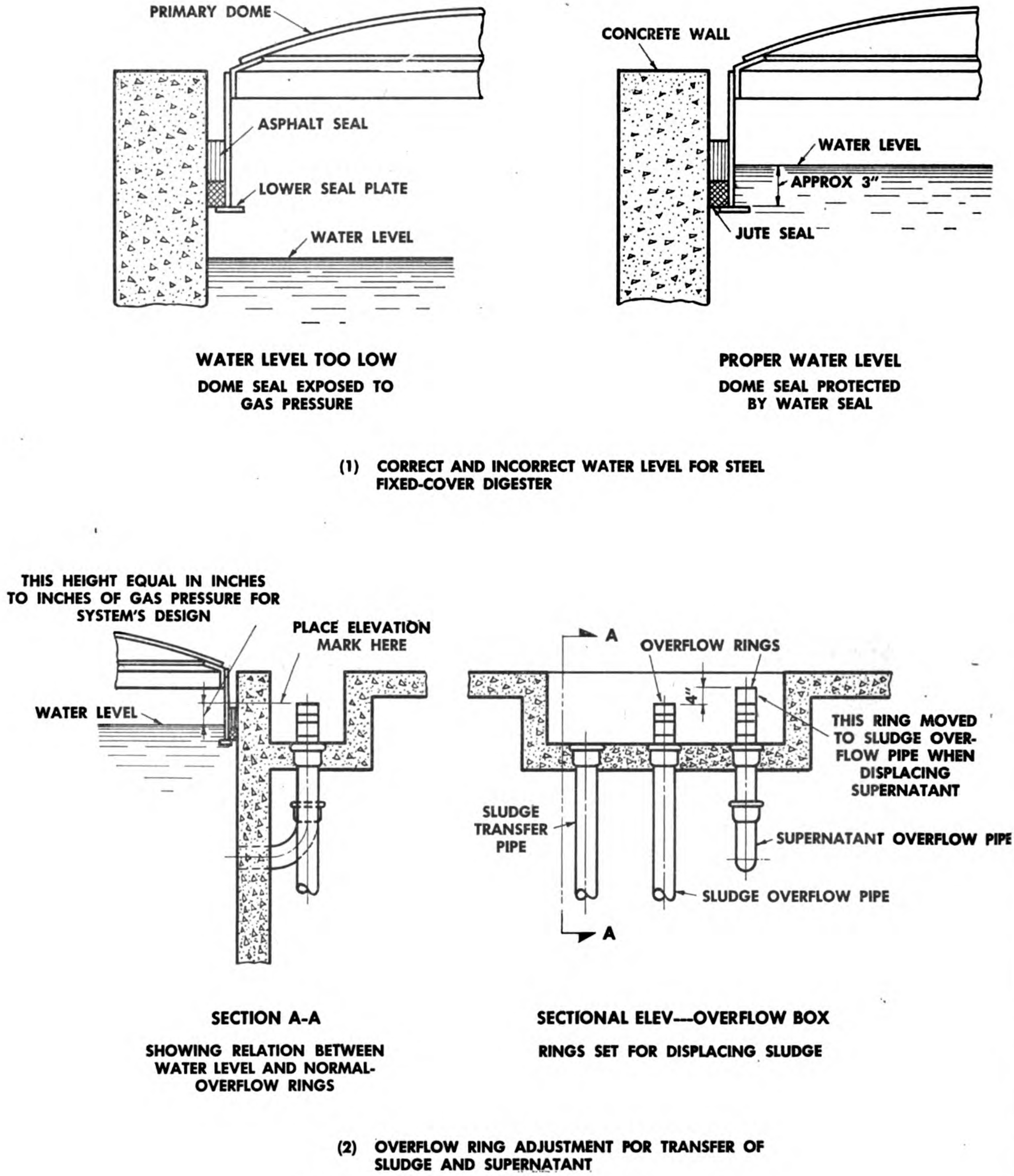
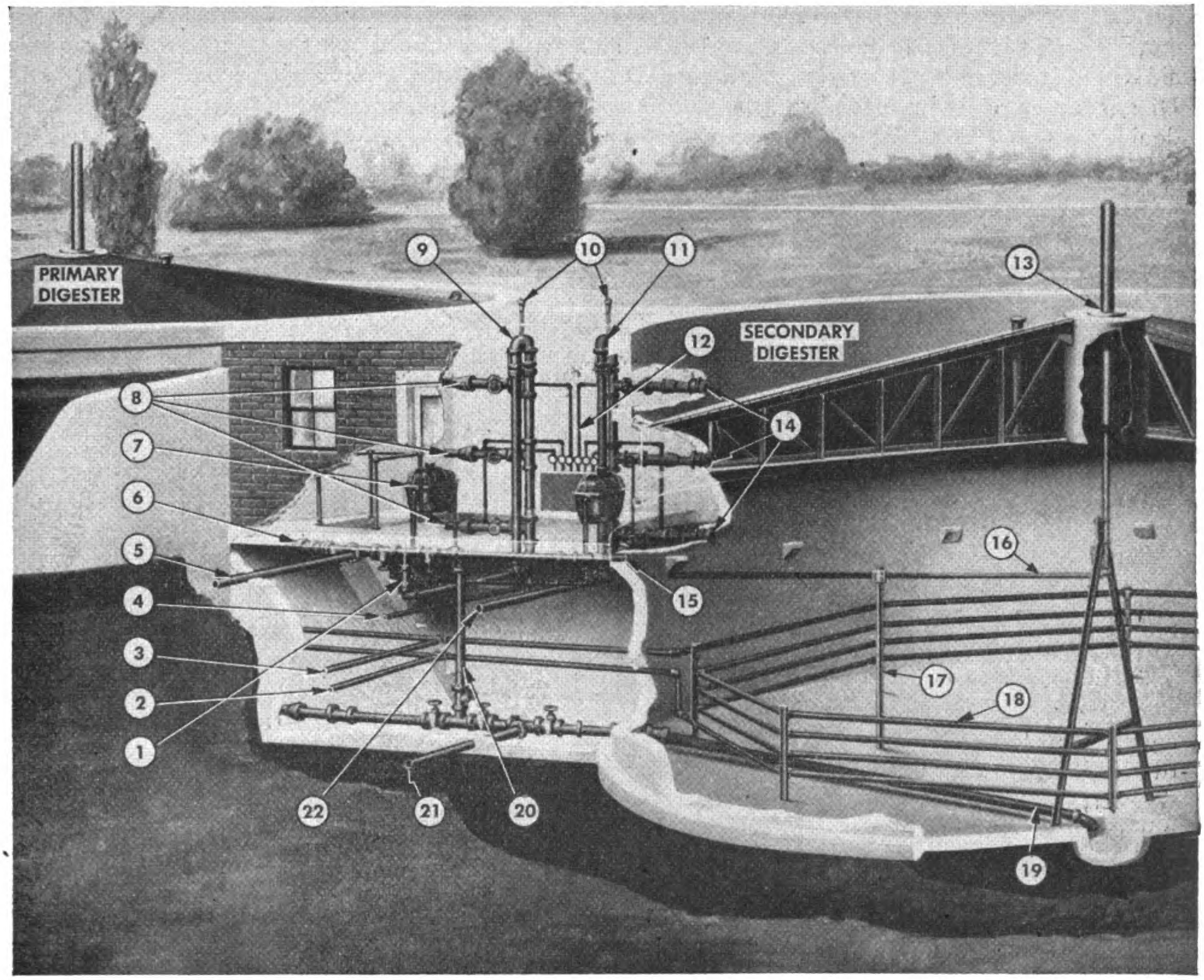


FIGURE 70. *Operating methods for fixed-cover digesters.*

proper proportions. The digested-sludge level is not too high until it interferes with the supernatant's quality. Where disposal facilities permit, sludge is withdrawn in smaller quantities, filling not more than one sludge bed at a time, once each month in smaller plants and as often as necessary in larger ones. The operator must stop drawing if any change in appearance indicates improperly digested sludge.

c. Well-digested sludge is usually granular, has a tarry odor, is dark in color, and has a volatile-



(1) Supernatant transfer pipe.
(2) Heating-water return pipe.
(3) Heating-water feed pipe.
(4) Gas line to boiler and waste burner.
(5) Raw-sludge pipe from primary settling tanks.
(6) Raw-sludge inlet to primary digester.
(7) Gas meter.
(8) Primary-digester supernatant outlets.
(9) Primary-digester supernatant overflow.
(10) Supernatant-overflow gas and air vents.
(11) Secondary-digester supernatant overflow.
(12) Supernatant sampling lines.
(13) Gas dome.
(14) Secondary-digester supernatant outlets.
(15) Secondary-digester inlet for partially digested sludge and supernatant.
(16) Secondary-digester gas line.
(17) Gas line support.
(18) Heating coil.
(19) Secondary-digester, sludge draw-off pipe.
(20) Sludge-transfer pipe.
(21) Digested sludge pipe to sludge beds.
(22) Secondary-digester supernatant pipe to raw sewage or other point of disposal.

FIGURE 71. *Piping arrangement for two-stage floating-cover digesters.*

solids content less than 55 percent of the dry-solids weight. Gray or light brown stripes in the sludge are signs of less digested material. Sludge drawing is done slowly to minimize disturbance of the digester. With floating-cover digesters, withdrawal should not be made when the cover is in the low position in the tank. With fixed-cover digesters, raw sludge should be pumped into the tank at the same time and at a rate at least as great as the digested sludge is withdrawn to reduce the danger of pulling air into the tank and to maintain gas pressure.

84. Temperature Control

Heating equipment must be put into operation as soon as possible and constant temperatures between 85° to 95° F. maintained. (See par. 98.) Water temperature in the heating coils to the digester should not be above 140° F.; otherwise, sludge cakes on the coils forming an insulating layer which reduces efficiency. Digester temperature is determined at least once each week. Approximate temperature may be obtained by checking the supernatant, but thermometer wells installed in the digester are more

accurate. Digester temperatures at each 3-foot elevation are determined once each month with the aid of a wide-mouth-bottle sampler. (See par. 157.) Digesters are usually insulated by embankments or double walls. If digester temperatures cannot be properly maintained, construction of embankments should be considered.

85. Sludge Circulation

Circulating the sludge mixes raw sludge and seeding material in the tank. Where the recirculation enters at the top of the tank, scum formation is broken. Recirculation also helps maintain alkaline fermentation. Where need is indicated, digested sludge may be pumped back to the top of the digester for at least 1 hour each day after supernatant withdrawal.

86. Mechanical Stirrers

Stirrers break up scum, keep grit removed from floor, and mix seeding material with incoming sludge. This equipment is usually driven by an electric motor through a reduction gear and should be equipped for automatic shutoff and alarm in case of overload. (See TM 5–666.) On the single-stage digester, stirring equipment is cut off at least 60 minutes before supernatant or digested-sludge withdrawal.

87. Scum Control and Foaming

a. General. Digesters operating within the recommended temperature range normally have a top layer of scum, usually a mat containing matchsticks, hair, and other light material that is hard to digest bound together with grease and other sludge solids. Gas bubbles carry up entrained solids which deposit in the scum. These solids settle again partially or totally. Normally the scum need not be disturbed. Grease is readily digestible if it is kept wet and warm. If excessive greasy scum forms, pumping skimmings to digester is discontinued. The bottom of the scum should be kept 1 or 2 feet above the supernatant overflow pipe, otherwise scum may discharge with or clog the overflow.

b. Scum removal. Since temperature in the upper part of the digester may be 20° to 30° F. lower than the rest of the tank, scum formation may be lessened by insulating the digester cover to maintain higher temperatures at the top. Wetting and warming the scum layer, recirculating sludge or supernatant to the top of the digester, or raising digester temperature to 95° or 100° F. helps break up the scum. Where the layer is excessively thick, it can only be broken and removed by manual labor.

c. Foaming. Causes of foaming and methods of control in Imhoff tanks (par. 66) are the same in separate sludge digesters. Maintenance of proper digester temperature (par. 84) prevents foaming unless tanks are grossly overloaded or seed sludge is depleted (par. 83).

88. Two-Stage Operation

Two-stage digestion uses two compartments, primary and secondary; it may also be done in the two-story digester. This method separates the violet initial digestion from the slower final period. At optimum temperature ranges digestion is about 66 percent complete in 5 to 18 days and 90 percent complete in 14 to 27 days. In the primary tank, incoming raw sludge is well mixed with seeding material and tank contents kept relatively homogeneous by mechanical stirring or recirculation if necessary. However, some sludge separation occurs with denser material going to the bottom of the tank. Digestion is completed in the secondary tank where gas evolution and resultant mixing is relatively slow; much clearer supernatant can usually be separated than in single-stage digestion.

a. Starting operation. Starting digestion in the primary tank is described in paragraph 80; the secondary tank is started at the same time by being filled with raw sewage. Until alkaline fermentation is established in the primary tank, only the supernatant is transferred to the secondary through the automatic overflow.

b. Transfer and withdrawal. (1) *Fixed-cover primary.* Supernatant or light sludge is normally transferred during sludge pumping from the fixed-cover primary tank to the secondary through the supernatant transfer line and box. When this liquid becomes high in solids content, the transfer is made from the bottom of the primary for 1 to 2 days. Figure 70 shows correct level and overflow-ring adjustment for transfer of supernatant and sludge. Supernatant and digested sludge is withdrawn from secondary digester as described for single-stage units. (See pars. 82 and 83.) The gas-holder-cover type of secondary is operated at maximum liquid level except when sludge is withdrawn, the cover providing a 5-foot drop in liquid level for this purpose. If the pH in the primary drops below normal, sludge may be pumped from the bottom of the secondary digester to the primary to

provide additional seed and maintain alkaline digestion. Supernatant must be transferred from primary to secondary simultaneously. Since temperature in the secondary digester is normally maintained 5° to 10° F. below the primary to improve supernatant separation, heating is necessary only during the coldest part of the year. Temperature should be increased to 90° or 95° F. if complete digestion is not obtained.

(2) *Floating-cover primary.* A floating-cover primary digester may be operated the same as the fixed-cover type with automatic supernatant or light-sludge transfer through the overflow piping. Figure 71 shows control piping for a two-stage floating-cover digester. As an alternate, the transfer may be made once every 2 or 3 days. In other respects, operation is similar to two-stage fixed-cover digesters.

89. Operation Control

Maximum digester efficiency can be obtained only by using careful digester observations and adequate laboratory analyses. (See sec. XVII, ch. 4.) The observations include digester temperature and volumes of raw sludge, digested sludge, supernatant, and gas; the analyses are those for total solids, volatile solids, pH, and in some cases gas content. These observations and analyses are limited by the metering and laboratory facilities available.

a. SLUDGE AND GAS VOLUME. Volume of sludge added or withdrawn and the volume of gas produced are measured or estimated. Gas measurement requires meters which may not be available. On floating-cover digesters, sludge volumes may be estimated by observing rise or fall of the cover. A table showing digester volumes for various depths saves repeated calculation.

b. RAW-SLUDGE ANALYSES. Raw-sludge analyses include determinations of percent total and volatile solids. Digester loading is usually expressed in pounds of volatile solids added daily per cubic foot of digester capacity.

c. DIGESTER ANALYSIS. Digester analysis includes determinations at least once each month showing temperature, pH, and total and volatile solids at each 3-foot depth in the digester. Degree of digestion at the various depths is determined from these data as well as general condition of digestion process. The operator uses these tests to control withdrawals, recirculation, etc.

d. GAS ANALYSIS. Rate of gas production and composition of gas indicate digester activity. Several factors govern the volume of gas obtained from digesters, particularly degree of digestion and character and amount of volatile solids in the material. Gas volume produced is expressed in terms of the number of persons served, weight of volatile solids in the raw sludge, or the weight of volatile matter destroyed by digestion; it usually ranges from 0.7 to 1.2 cubic feet per capita per day or from 6 to 12 cubic feet per pound of volatile matter in raw sludge. Sludge gas usually contains 60 to 75 percent methane, 20 to 35 percent carbon dioxide, 1 to 10 percent of nitrogen, and small quantities of hydrogen, sulfide, hydrogen, and oxygen. Analysis for carbon dioxide only is enough for routine control. Close observation and recording of the gas production and a weekly gas analysis effectively measure digester activity. High rate of gas production with carbon dioxide content below 30 percent indicates good digestion; increasing carbon dioxide content shows trend toward acid digestion.

90. Record for Digesters

a. MONTHLY OPERATING LOG. Monthly operating logs show the following:

(1) Gallons of raw sludge pumped.

(2) Percent solids and percent volatile matter in raw sludge.

(3) Monthly digester analyses showing temperature, pH, percent solids, and percent volatile solids at specified sampling points or depths.

(4) Cubic feet of gas produced daily.

(5) General appearance and disposition of supernatant.

(6) Gas analysis when made.

b. DAILY RECORDS. The following daily records are kept in addition to those required for the monthly report:

(1) Hours of pumping raw sludge.

(2) Temperature of water to and from heating coils.

(3) Depth of sludge in tanks.

(4) Dates at which sludge is drawn from digester.

(5) Remarks on foaming or other special operating conditions.

91. Uses for Digester Gas

Sewage gas is commonly used for heating water to maintain digester temperature; other uses include building heating, laboratory burners, screening and grease incineration, or gas engines driving pumps,

blowers, or electric generators. Excess gas is burned in a waste-gas burner. Since fixed and floating covers with gas domes have a limited gas-storage capacity, gas-holder covers and separate gas-storage tanks are sometimes provided.

92. Gas Dome Seal

Gas domes having a liquid seal permit gas to escape when the pressure becomes too high and allow air to enter when removal of sludge or supernatant liquor tends to create a vacuum. The seal rings should always be properly filled. Liquid in the seal should never exceed 10 inches of water or its equivalent; if all gas is burned to waste, much less seal depth is necessary.

a. Liquid seals. Water is usually used in the seal, automotive antifreeze compounds being added if necessary to prevent freezing. If the seal ring is tightly constructed, kerosene or light oil may be used in place of water. The seal ring must have an overflow to prevent putting in too much liquid causing high pressures to develop. The liquid seal is an excellent safety valve permitting the escape of gas if a valve from the gas dome is closed or the pipe is obstructed.

b. Escaping gas. Signs of escaping gas at the seal are investigated. The cause may be a result of the following:

(1) Insufficient depth of liquid in the seal ring.

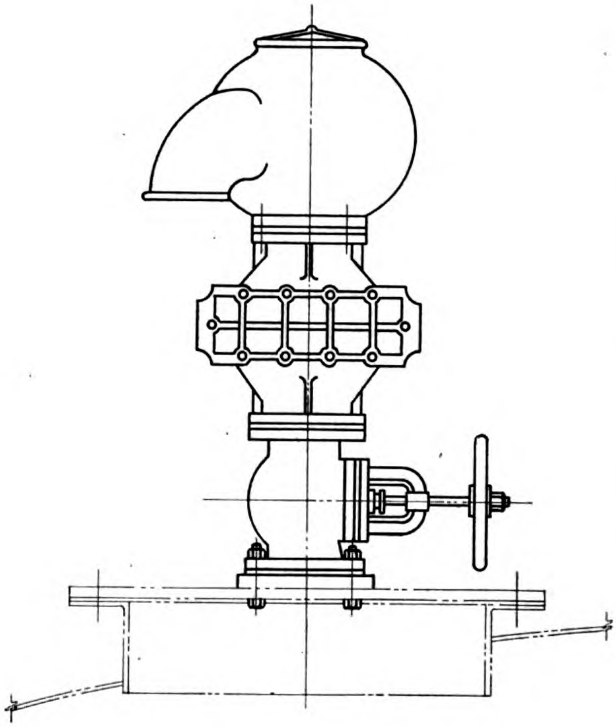
(2) Gas pipe from the gas dome too small or closed by valve.

(3) Freezing of moisture in pipes.

(4) Condensate collected in moisture traps or in low portions of pipe line.

93. Pressure-Vacuum Relief and Flame Arrester

Two types of pressure-vacuum relief units commonly used on digester covers are shown in figures 72 and 73; they usually take the place of the liquid seal although some covers may have both. The pressure relief is set to allow gas to escape when the pressure exceeds a predetermined value. The vacuum relief allows air to enter the digester if a vacuum is produced. The relief equipment usually incorporates a flame-arresting element which has a cell of alternately smooth and corrugated aluminum strips with openings that permit escape of gas but arrest the flame. The Varec flame arrester should be installed between the relief valve and a gate valve which connects the entire unit to the digester. The gate valve is closed to avoid losing gas when inspecting and cleaning the flame arrester but must always be open during normal operation to prevent collapse or lifting of cover by gas; it is locked in open position by U-bolt or other means. TM 5-666 describes preventive maintenance and operating adjustments for flame arresters.



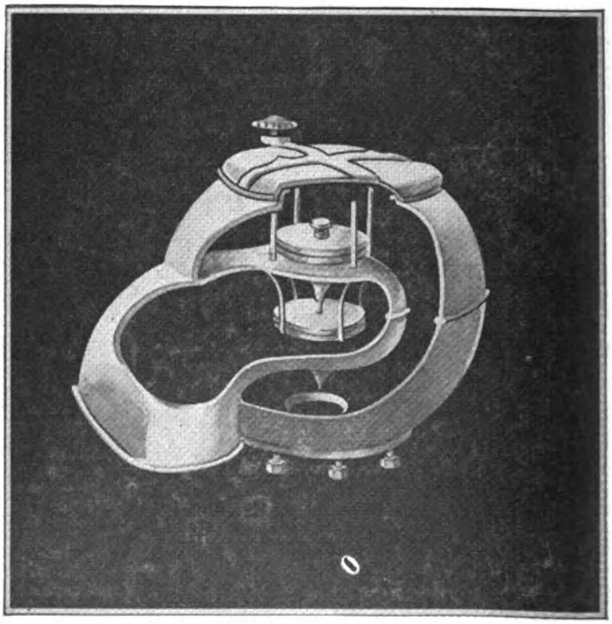


Figure 72. *Varec pressure-vacuum relief.*

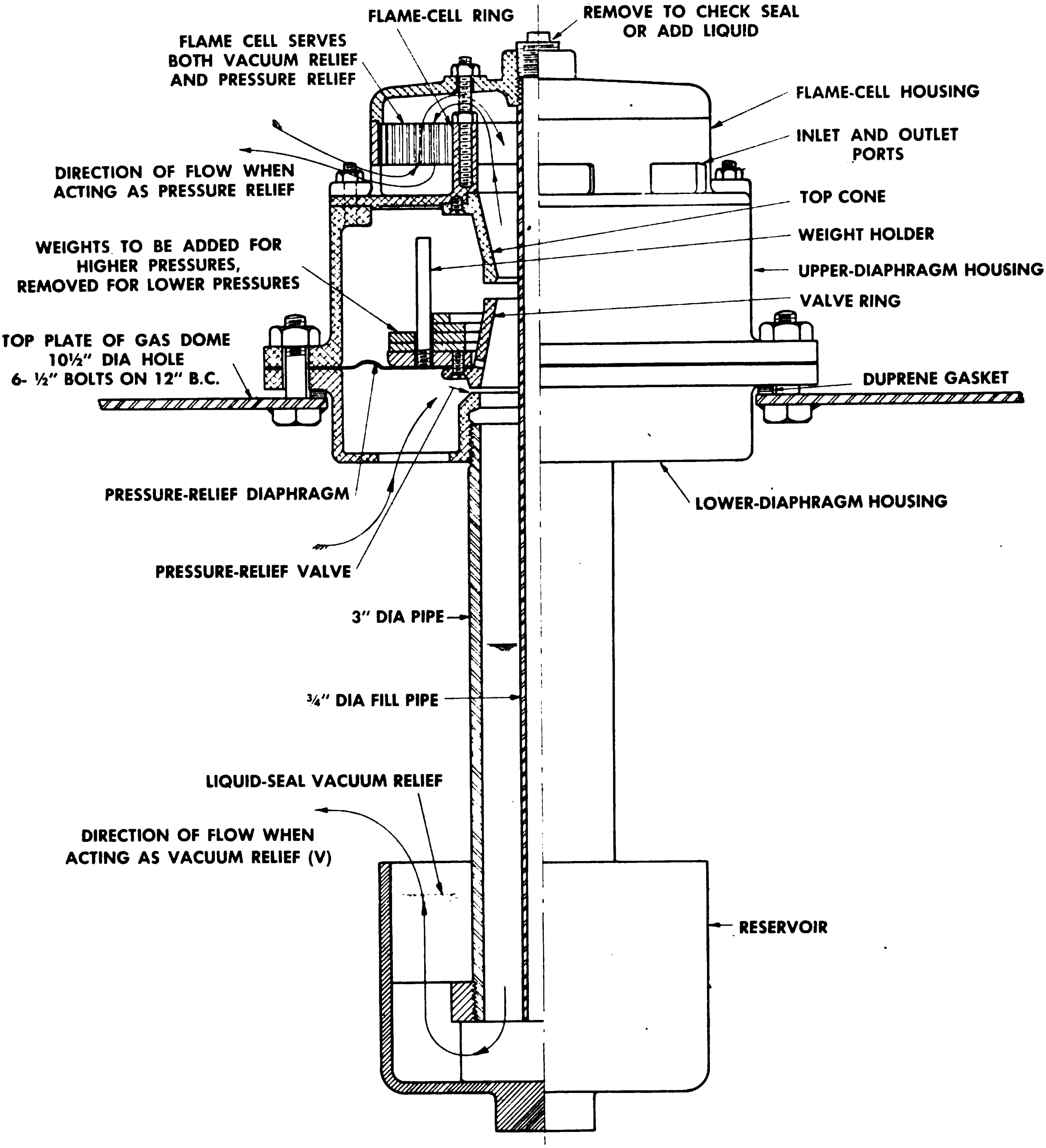


FIGURE 73. *PFT pressure-vacuum relief assembly.*

94. Drip Traps

Sludge gas carries considerable moisture which condenses on the pipe surface and fills low points. All gas lines must slope toward adequate drip traps where the moisture may be collected and periodically removed. These traps must be protected from freezing. If buried lines settle creating a low point where moisture may accumulate to block passage of gas, they should be uncovered and relaid on uniform slope. The trap shown in figure 74 permits removal of condensate without allowing sludge gas to escape during the operation; manually-operated types provide 2- to 2½-quart capacity and normally have a valve open to the gas line. The traps must be drained daily by turning the handle which closes off the inlet and opens a visible drain.

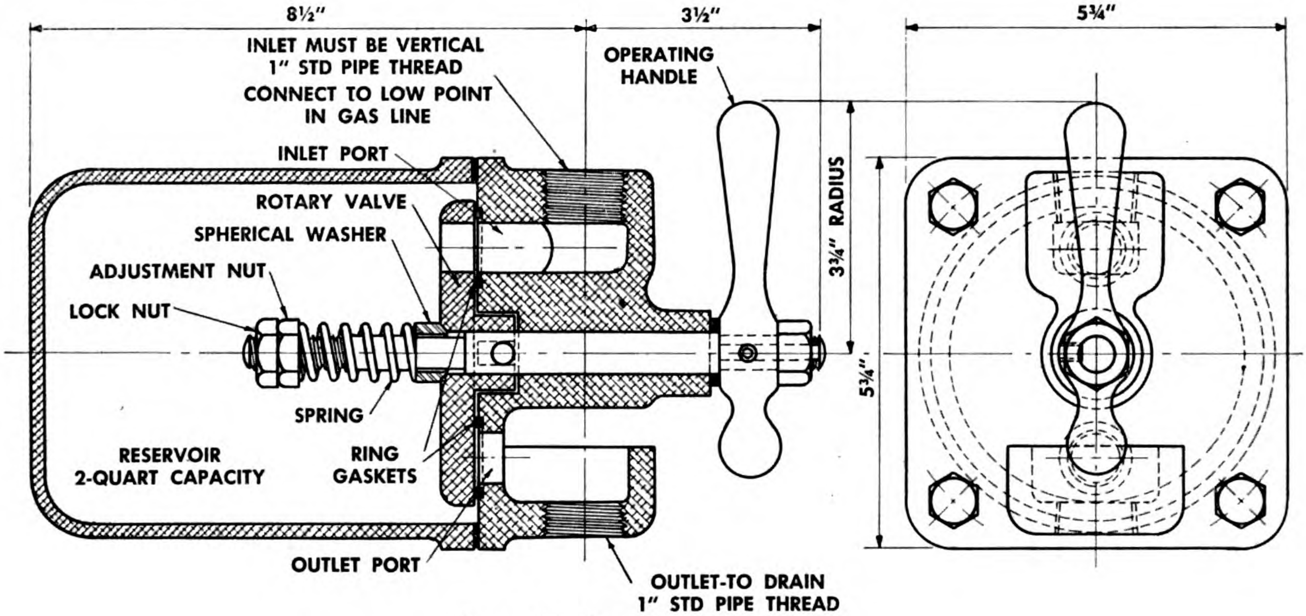


FIGURE 74. *Manually-operated drip trap.*

95. Flame Traps and Waste-gas Regulators

Flame traps must be installed in all gas lines within 25 feet of the source of all flames such as boilers, waste-gas burners, building or laboratory burners, incinerators, or gas engines. They stop any flame which might cause digester explosion and are similar to those described in paragraph 93.

a. FLAME TRAPS. The unit shown in figure 75

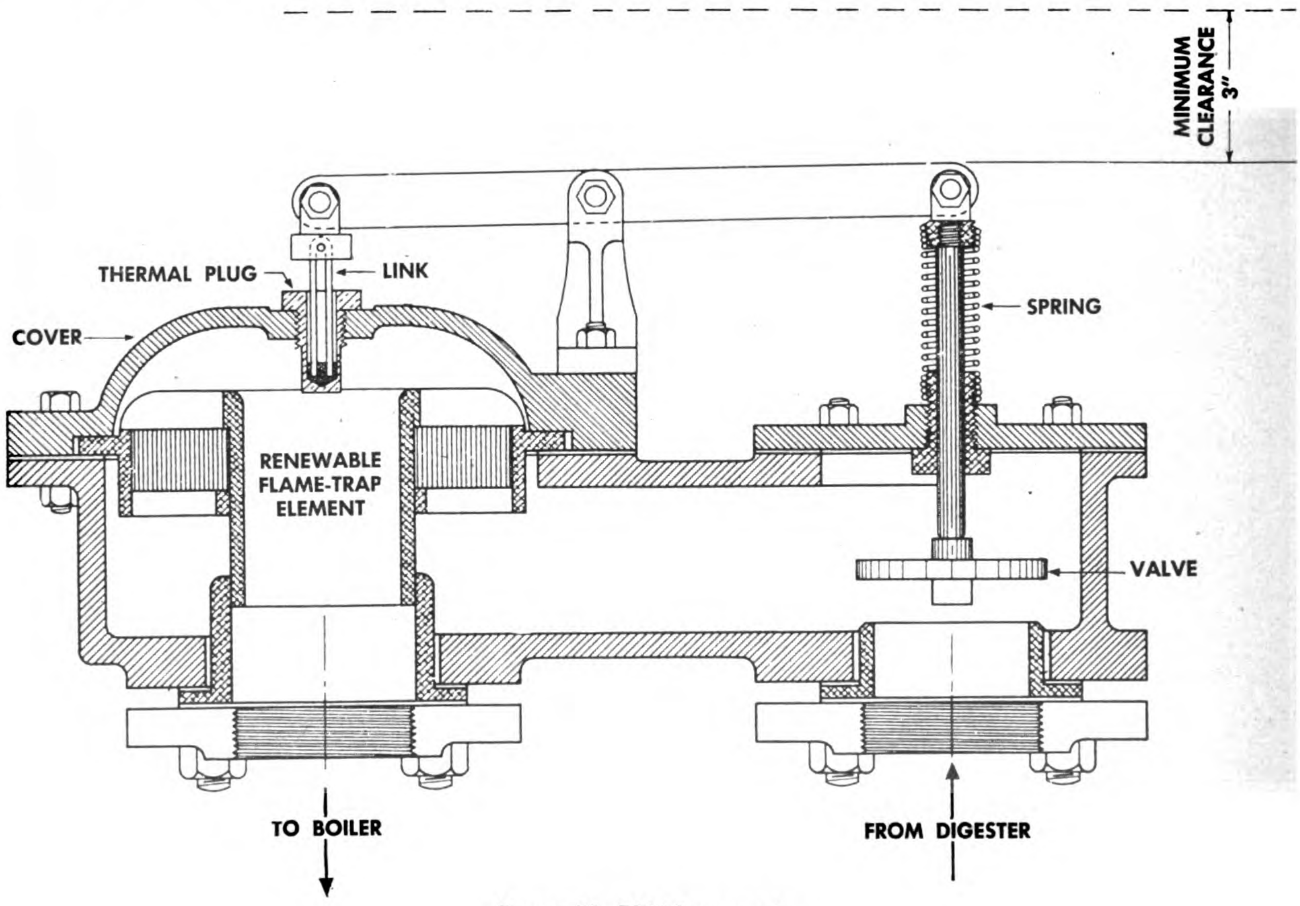


FIGURE 75. *PFT flame arrester.*

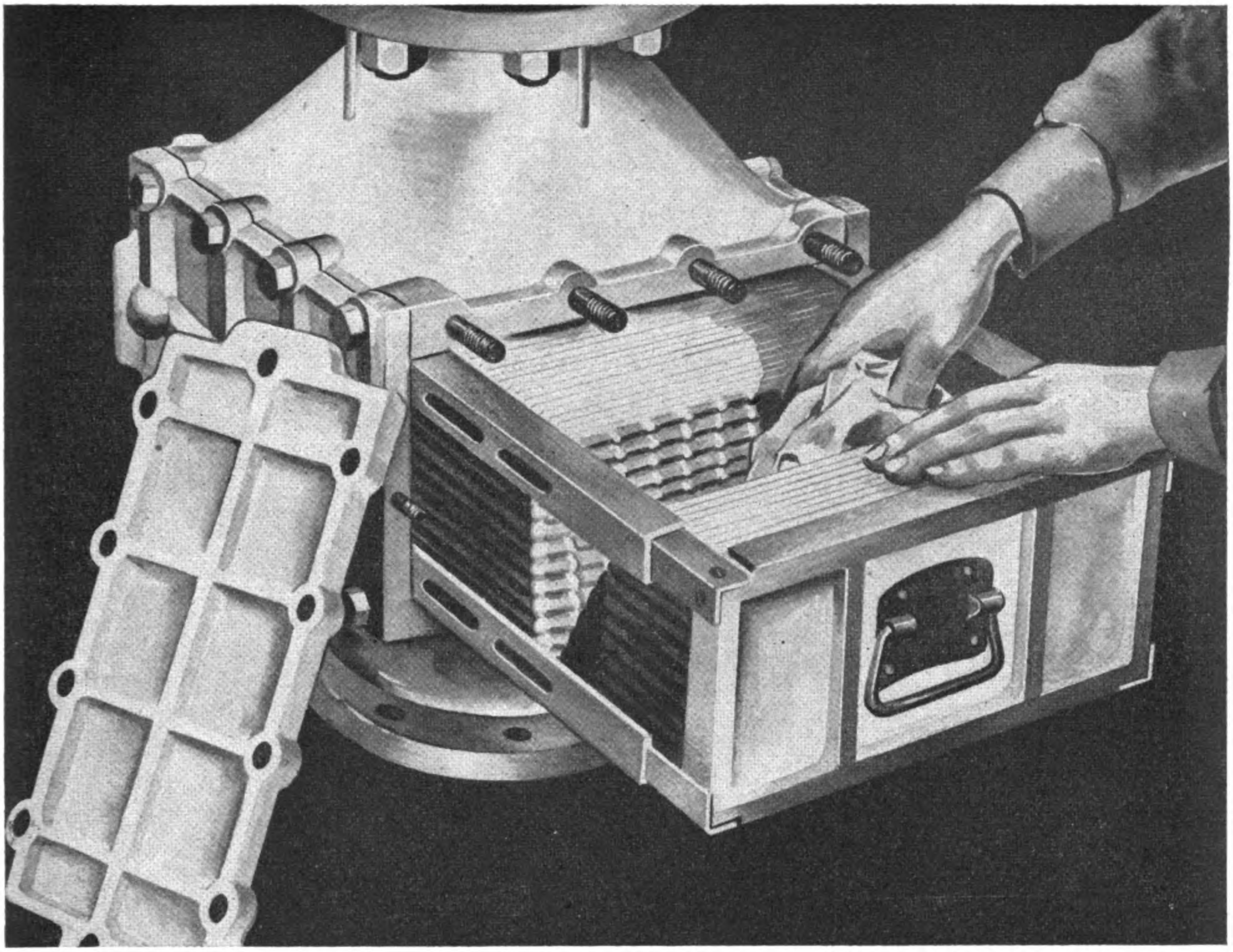


FIGURE 76. *Varec flame arrester.*

includes arrester, or flame-trap element, and a thermal-operated shut-off valve which closes a valve on the approach side of the arrester when heat generated by flame is enough to melt fusible plug. Figure 76 shows a Varec flame arrester.

b. WASTE-GAS-REGULATOR. When part of the gas is used with the excess going to the waste-gas burner, the line to the burner usually has a combination flame trap and pressure relief. (See fig. 77.) The relief allows excess gas to pass automatically to a waste-gas burner; the flame trap protects the gas-collection and distribution system against flame from the waste-gas burner. Pressure must be adjusted 1 or 2 inches below that operating pressure-vacuum relief on gas dome but great enough to operate the gas boiler.

c. FLAME CELLS OR CHECKS. Flame cells are intended for flame protection only on minor lines where the maximum flow is 100 cubic feet per hour or less and are made of aluminum strips or mesh. They are usually used in gas pilot and laboratory lines and placed in vertical runs of pipe. Figure 78 shows an auxiliary flame cell for a small gas line.

96. Waste-gas Burners

Gas produced in a covered digester should be utilized or burned to waste because it causes disagreeable odors if allowed to waste to the atmosphere. Special waste-gas burners, usually installed at the treatment plant have a pilot line burning either digester or domestic gas and a digester waste-gas supply line. If the pilot line burns digester gas, it connects from the waste-gas line ahead of the pressure-relief and flame-trap assembly to provide a constant source.

a. MOISTURE. The supply line and pilot line connected to the pedestal base must drain to accessible low points for moisture removal. Where these lines pass through an earth fill, particularly

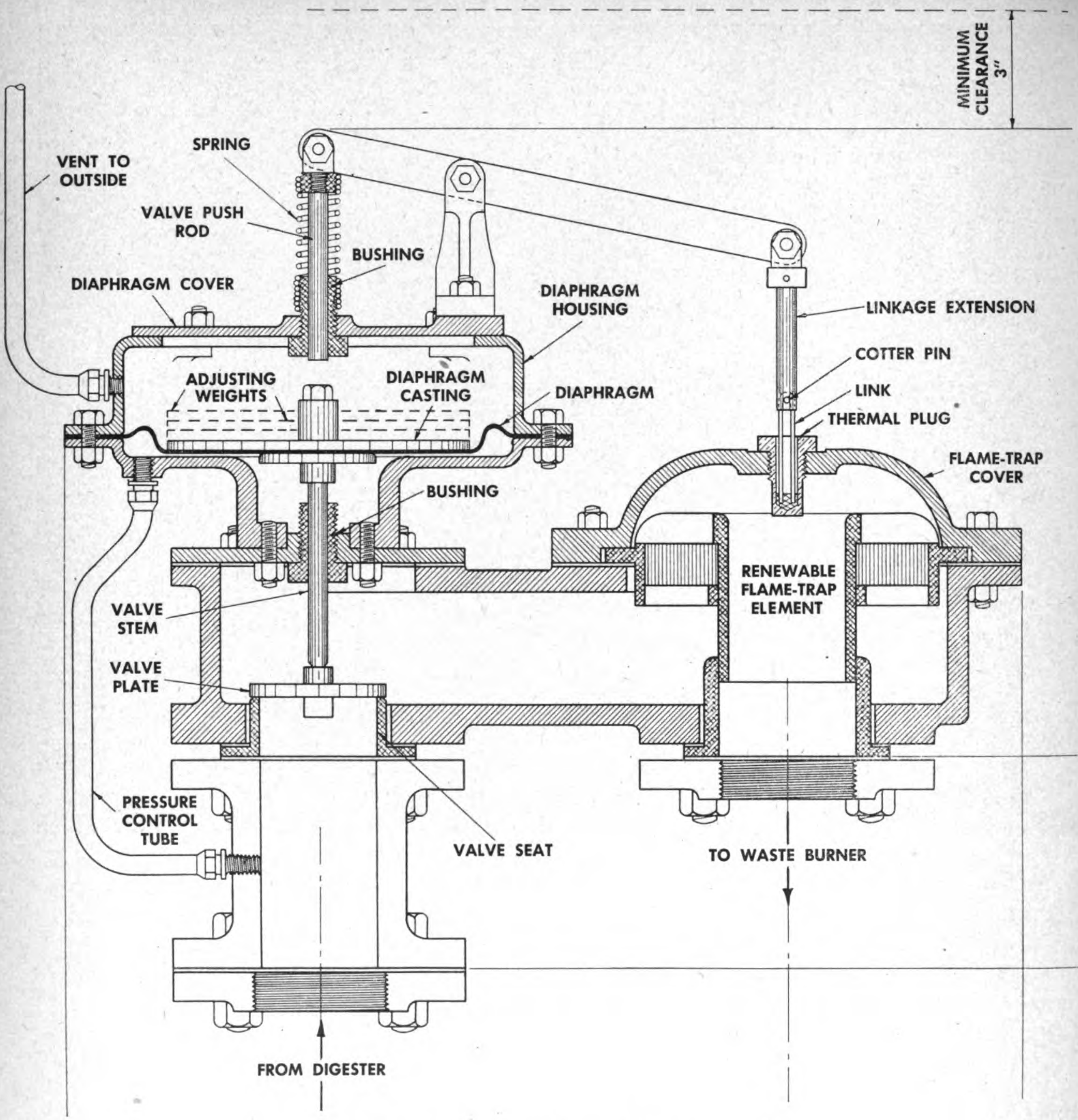


FIGURE 77. *Waste-gas regulator with flame arrester.*

beneath roadways, settling may cause low points which clog with moisture. If gas comes through irregularly or is heard to bubble, the line should be relaid with adequate support. The smaller pilot is often attached to the larger supply pipe for support.

b. STARTING OPERATION. Gas production starts with low quantity and quality. This first gas is passed through the system to the pressure relief and the waste-gas burner. When the quality improves after a few days, the waste-gas burner is lighted by holding a flame over the top of the burner pot.

c. TYPICAL BURNER. A common type of waste-gas burner is shown in figure 79. The burner rests on a pedestal through which pass the main supply line and pilot line. The space around these lines inside the pedestal (1) is insulated to protect against

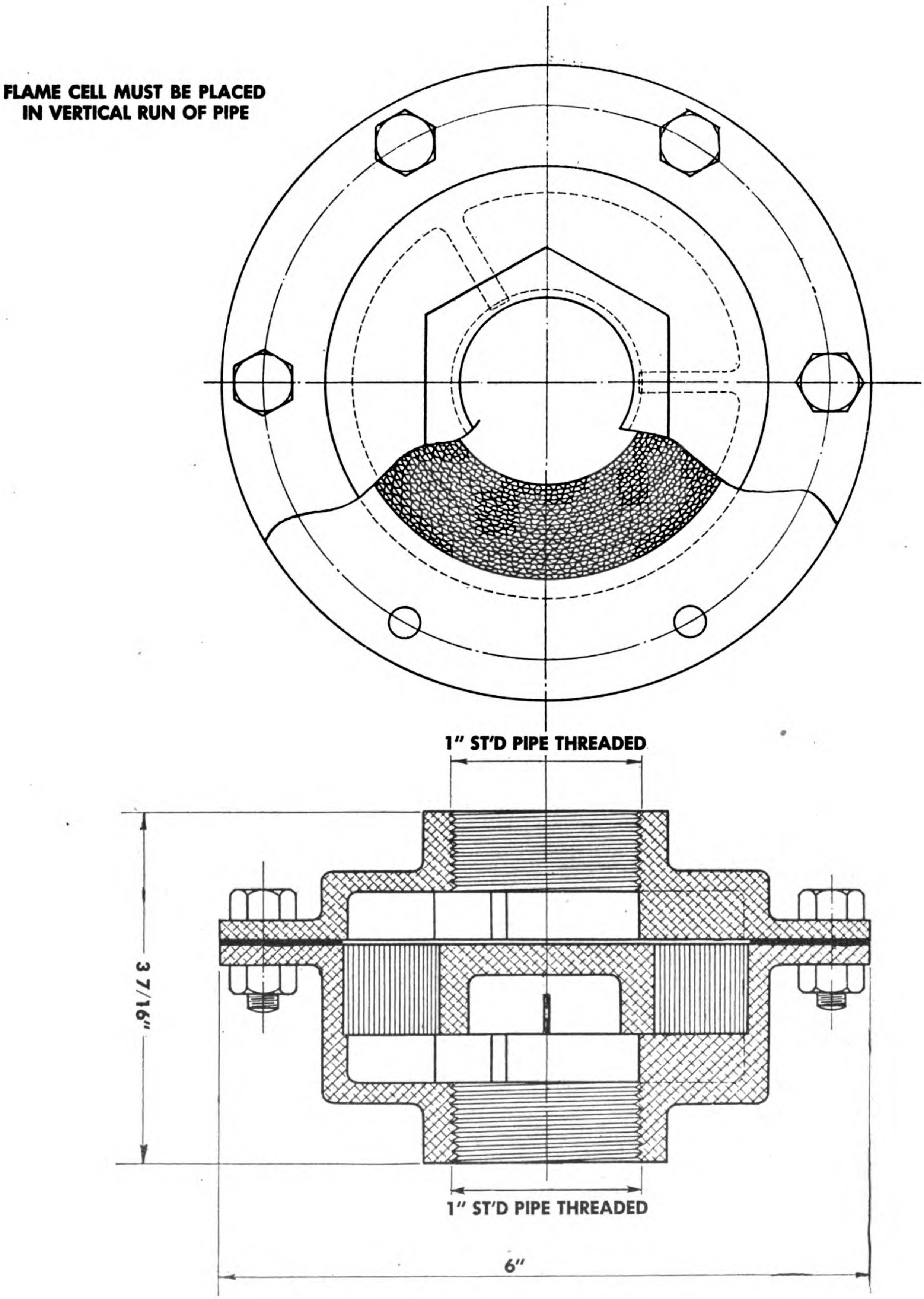


FIGURE 78. *Auxiliary flame cell for small gas lines.*

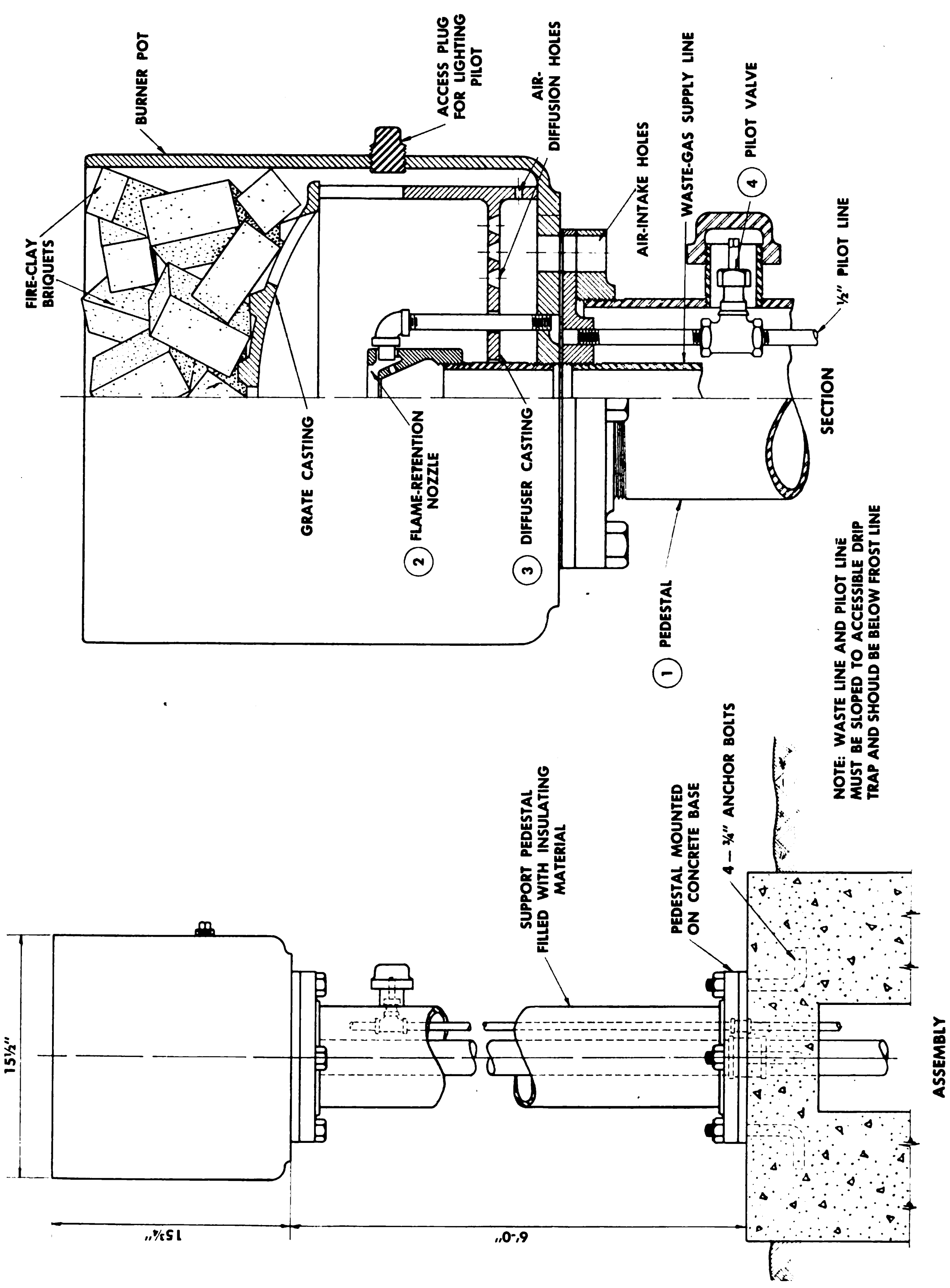


FIGURE 79. *Waste-gas burner.*

frost. The burner has a nozzle (2) at its center and a valved pilot supply for ignition. Air enters the burner bell from beneath, passes through the diffuser casting (3) which protects against wind, and mixes with the gas above the burner nozzle. The pilot valve (4) is adjusted to give a 2-inch flame. Unless the gas supply is limited, the valve should be operated well open. Where severe winds prevail, a supplementary sheet-metal shell about 18 inches in diameter and 30 inches high extending above and below the burner bell may be installed. A pipe 6 inches in diameter and 8 inches long placed upright on the briquets or an iron grid laid over the burner may improve exposed installations. Preventive maintenance instructions for waste-gas burners are given in TM 5–666.

97. Pressure Gauges

a. General. Many gas-distribution systems have gauges or manometers to measure the actual gas pressure in various parts of the system. Frequent observations help the operator keep the system free of moisture and in good operating condition. Three gauges are usually provided to measure pressure at the digester, point of use, and supply to the waste-gas burner. Each scale has three-way cocks which close off the gas supply and vent the gauges to the atmosphere when readings are not being taken. One type, shown in figure 80, is calibrated to use oil with specific gravity of 0.90 (OE 10) and designed for a maximum pressure of 8 inches equivalent water column. The tops of the gauge glasses should be connected to an outside vent to avoid excessive pressure forcing out the oil and permitting escape of gas into the room.

b. Adjustments. The only adjustment to be made concerns the zero position of the liquid in the gauge glasses. In adding the oil initially, connections to the top of the reservoirs should be removed and oil added until the level reaches zero on the scale. If too much oil is added, it may be removed through drain plugs in the bottom of the reservoirs. Minor additions to bring the level to zero can be made simply at the top of the glass tube after the cover is removed, allowing time to find its level inside the tube. In this instance, the connection from the top of the reservoir to the gas system should be vented at the three-way cock.

98. Gas Boilers

Digester-gas-fired hot-water boilers heat the sludge digester and frequently plant buildings; they must be fully equipped with all necessary protective devices and auxiliary equipment, such as gas-pressure governors, thermostatically-controlled gas valves, thermostatic pilots, low-water cut-offs, and safety valves.

a. The boiler is operated at 180 ° F. so moisture condensation within the flue is at a minimum; circulating water is kept at 140° F. or less by the thermostatically-controlled three-way valve which mixes the water from the boiler with the cooler water direct from the coils of the digester or by manual setting of valves in the lines. A complete boiler-room arrangement is shown in figure 81.

b. Before starting the boiler, all gas should pass through the waste-gas burner until a readily burnable gas is obtained. The pressure-vacuum relief, gas-dome seal, and pressure-regulating valve in the waste-gas-burner line must be checked and adjusted. (See pars. 93 and 95.) If orifices in the burners are not the proper diameter to burn digester gas, replacement must be made. Where boiler operation is started with domestic or bottled gas, original orifices must be changed in accordance with manufacturer's recommendations while digester gas is not in use.

99. Records for Gas Equipment

The following records are kept on gas equipment:

a. Gas pressures.

b. Temperature of circulating water leaving and entering the digester.

c. Temperature of boiler water.

d. Daily production of gas if meters are available.

e. Volume of gas wasted if meters are available.

f. Remarks concerning any unusual operation.

Section IX. SLUDGE DRYING AND DISPOSAL

100. Sludge Beds

Well-digested sludge from the separate sludge digester or Imhoff tank has a water content of 90 to 96 percent. Digested sludge is generally dewatered at the treatment plant by underdrained sand beds, although natural sand areas are sometimes used. This sludge drying takes place both by evaporation from the surface and drainage through the sand and gravel. Water passing through the bed is returned to the raw-sewage flow where possible. When plant elevation makes this impracticable, it is discharged to other points in the plant or to the receiving stream.

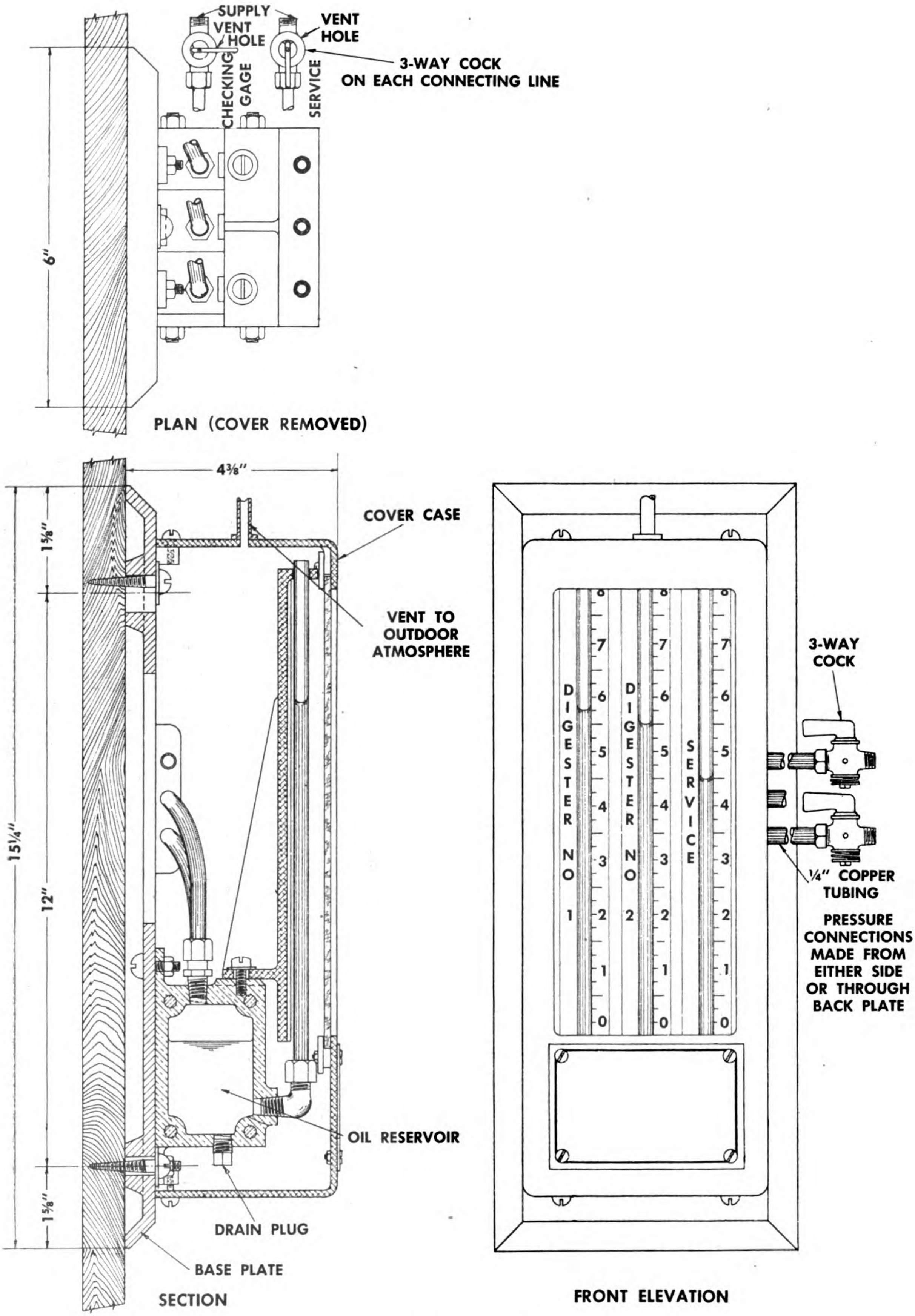
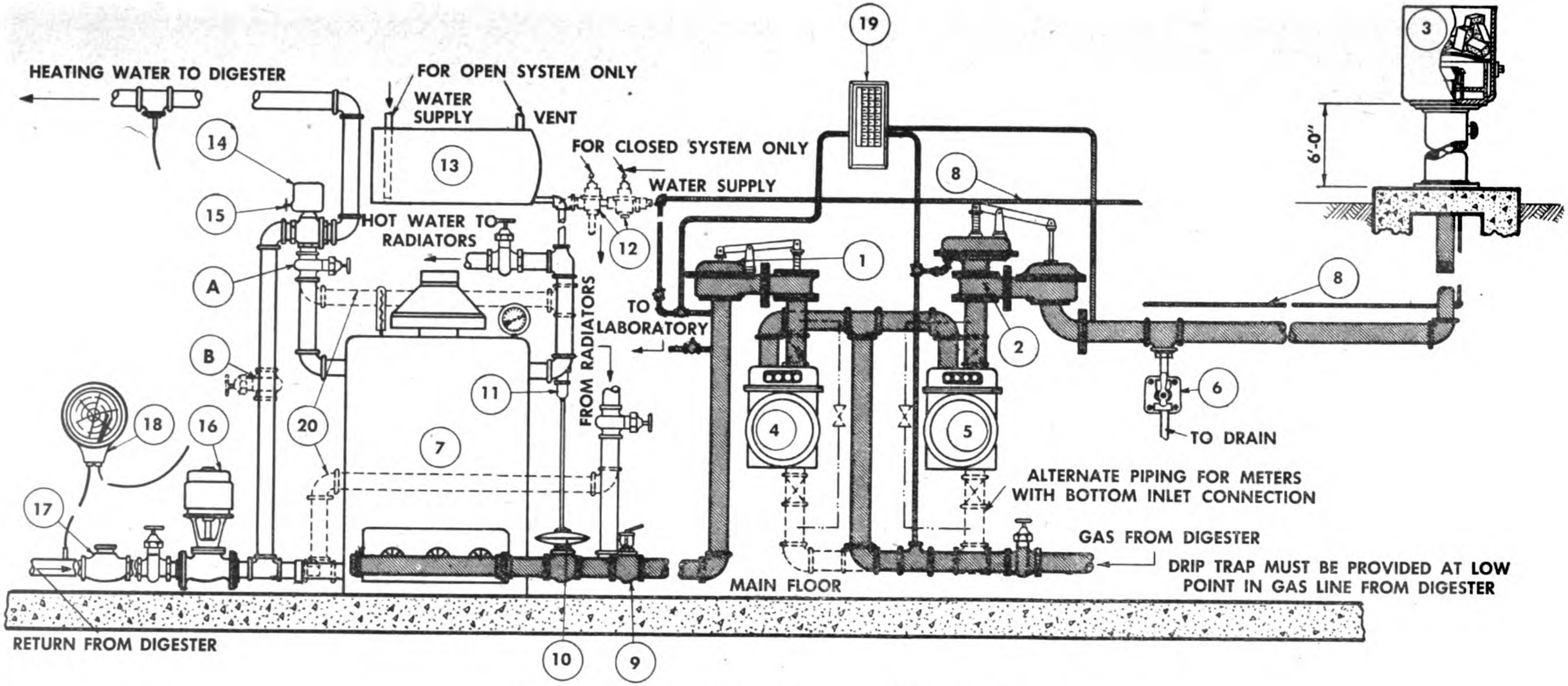


FIGURE 80. *Gages for digester-gas distribution system.*



NOTE: TO PREVENT CONDENSATION FROM BURNING GAS, MAINTAIN BOILER AT 180° F CIRCULATE WATER TO DIGESTER AT 120° TO 130° F BY BLEEDING FROM BOILER, REGULATED BY THREE-WAY VALVE OR BY SETTING VALVES (A) AND (B)

METERS UP TO 117 CU FT PER HR AT 0.3" LOSS MAY BE SUPPLIED WITH BOTTOM INLET CONNECTION

WATER METER (17) SHOULD BE INSTALLED IN SMALLER BYPASS

DOTTED LINES SHOW OPTIONAL BYPASSES

(1) Flame trap, type B.
(2) Pressure-relief valve, type B.
(3) Waste-gas burner.
(4) Boiler-gas meter.
(5) Waste-gas meter.
(6) Drip trap.
(7) Boiler.
(8) Pilot line to waste burner.
(9) Nonthrottling hand valve.
(10) Thermostatically-controlled gas valve.
(11) Thermostat.
(12) Pressure-reducing and -relief valves.
(13) Expansion tank.
(14) Thermostatically-controlled three-way valve.
(15) Thermostat.
(16) Water-circulating pump.
(17) Water meter.
(18) Two-pen temperature recorder (plain thermometers may be substituted).
(19) Pressure-indicating gage.
(20) Alternate piping for boiler supplied with single inlet and outlet connections.

FIGURE 81. *Arrangement for boiler-room piping and equipment.*

101. Construction

Underdrained beds ordinarily are level areas of sand supported by graded gravel layers having open tile drains; sand depth varies from 6 to 12 inches and gravel from 6 to 8 inches. Floors are natural earth with the dividing and outside walls of concrete, wood, or earth. The beds consist of a number of adjacent or independent units whose size depend upon plant size and average drying time. Standard design for Army construction of underdrained drying beds provides 1.0 square foot of sand surface per capita and for prepared natural areas, 2.0 to 3.0 square feet per capita. Glass-covered beds are used if climatic conditions or possible odor nuisance make them necessary. Figure 82 shows a sludge bed with concrete walls; figure 83, one with wooden walls.

102. Nature of Digested Sludge

Quick and efficient sludge drying depends on proper functioning of digester or Imhoff tank to produce well-digested sludge. Total-solids content of well-digested sludge varies from about 4 to 10 percent, volatile-solids content (dry basis) is below 55 percent, and pH, over 7.0. Poorly digested sludge forms a heavy, tenacious mat over both sand and sludge surface which slows drying; undecomposed grease clogs the sand. Where digestion is inadequate, the condition of the sludge adversely affects the drying and produces objectionable odors.

103. Operation

Operators must work out a schedule for drawing sludge from the digesters or Imhoff tanks to use drying or storing capacity for digested sludge to the best advantage. (See par. 83.) In summer or dry seasons when digestion and drying proceed rapidly, the beds can be recharged frequently. For unheated digesters or Imhoff tanks in cold climates, ripe sludge must be held in the tank during cold weather unless glass-covered drying facilities are available. During cold or wet weather, drying on open beds is retarded and partial storage of digested sludge in lagoons may be necessary. Lagooning of sludge or digester supernatant is generally done only as an expedient when other facilities are inadequate.

a. Sludge-bed preparation. Sludge beds must be clean before use. After dried sludge is removed and before a new batch is added, the sand surface is loosened by light raking and leveled with a slight slope away from the point where the wet sludge enters. Sludge chunks, weeds, and other debris are removed. When the sand layer decreases to 4 inches or less because of sand removed with the dried sludge, clean coarse sand is added. Improper

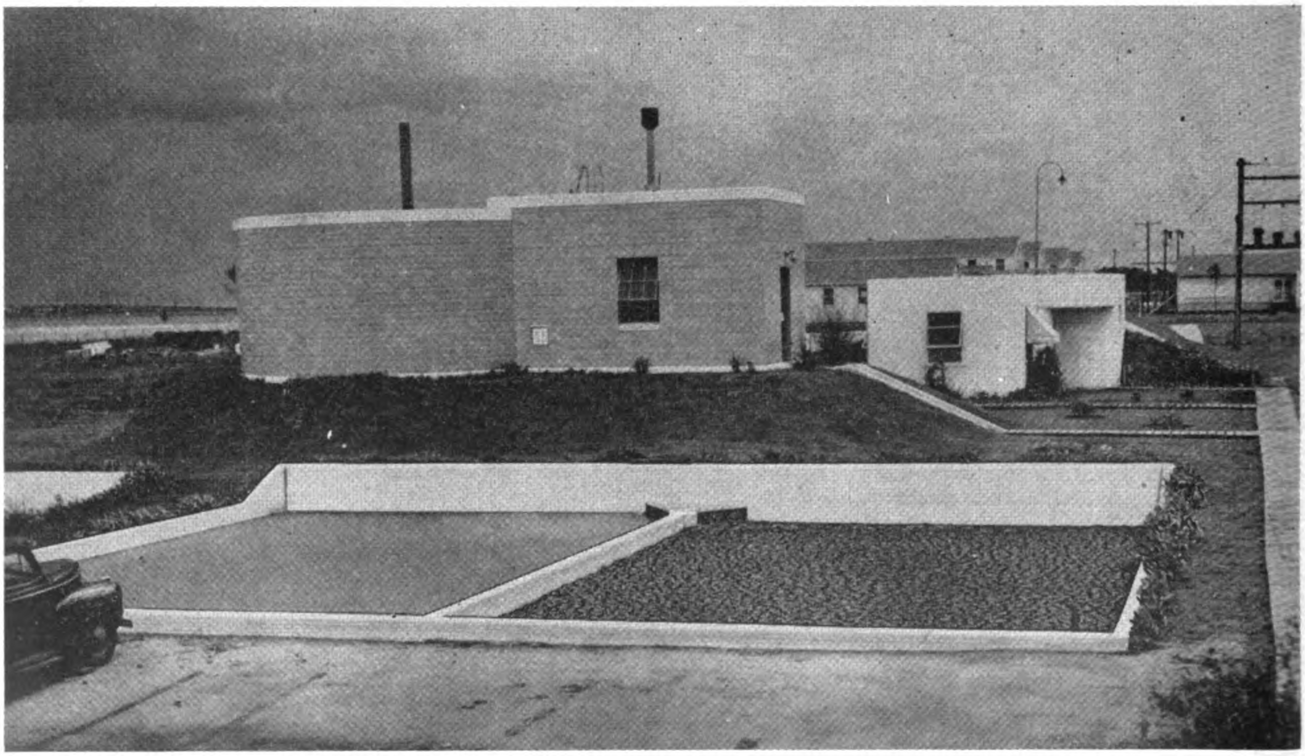


Figure 82. *Sludge beds with concrete walls.*

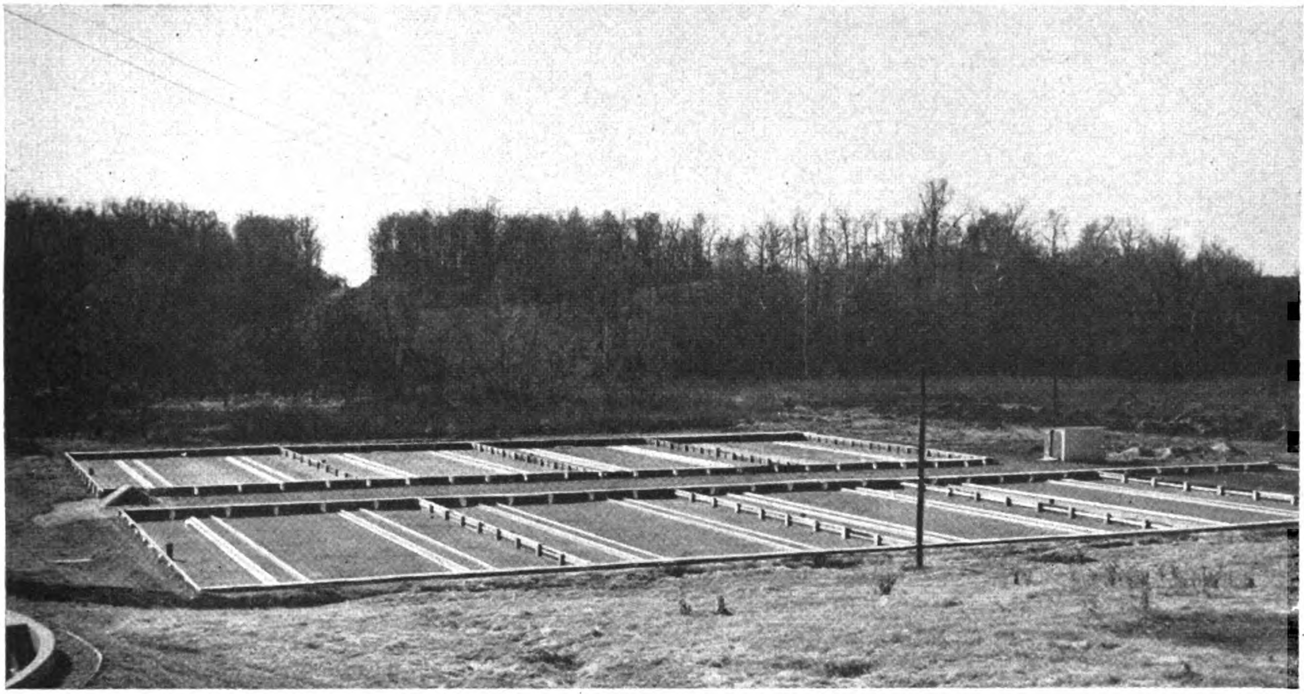


FIGURE 83. *Sludge beds with wooden walls. Note runways for trucks.*

cleaning and preparation of the beds between sludge doses may clog sand surfaces and retard drying. Clogged sand surfaces may be remedied by removing the top ¼ to 1 inch of sand. Sludge must be prevented from falling directly on the sand surface by an adequate splash plate of concrete, brick, masonry, or wood so the surface is not appreciably disturbed.

b. SLUDGE APPLICATION. (1) Filling the bed to excessive depths may clog the bed and lengthen drying time since water must then be lost almost entirely by evaporation. The depth for optimum drying, which can best be learned by experience is generally between 8 and 12 inches, depending on solids content. The dried cake should be about 3 to 4 inches thick under normal drying conditions. If the sludge is comparatively thin, it dries quickly, but the thinner cake requires more labor to remove a unit volume than thicker applications. A greater percentage of sand is removed with thin cakes. If bed area is limited, digested sludge must be drawn more frequently and applied at a minimum depth so it can dry more quickly. Wet sludge cannot be discharged onto dried or partially dried sludge. Sludge lines are drained and flushed with a small amount of water or supernatant after each use to prevent sludge hardening in them.

(2) If partly digested sludge or supernatant is drawn to the bed, hydrated-lime or chlorinated-lime suspension may be used to arrest decomposition Approximately 27 pounds of hydrated-lime suspension added to each 100 pounds of dry solids in the raw sludge permits drying without offense. However, the sludge dries slowly and incompletely; removal is difficult, and the sand clogs. Raw sludge is added only in extreme emergency.

c. COAGULATION. If the plant has insufficient sludge-bed capacity, the use of coagulants hastens the drying process. Alum solution is the most effective and economical agent for treating digested sludge before it is drawn to the sand beds. The proper amount can be determined by mixing known quantities of alum and sludge in the laboratory and observing how the sludge flocculates and separates from the liquid. Alum acts with the carbonates in the sludge to form carbon dioxide which keeps the sludge in suspension while the liquid drains off through the sand. As little alum as possible consistent with good results should be used; 1.0 to 2.0 pounds per cubic yard (200 gallons) of sludge are usually required. The solution is prepared by dissolving the aluminum sulfate, placed in a gunny sack and suspended in a barrel of water, by stirring or standing overnight; it is mixed with the sludge by siphoning it into the sludge inlet to the drying bed.

d. REMOVING DRIED SLUDGE. Dried sludge is ready to handle when it can be picked up with a fork without excessive sand adhering to the under-

side. Moisture content of this sludge usually ranges from 55 to 70 percent. To avoid removing too much sand, forks rather than shovels should be used. Dried material may be moved from the bed by wheelbarrows, trucks, tractor, or cart. Trucks or other heavy equipment are not allowed on the beds unless runways are provided to avoid crushing and clogging the underdrains.

104. Records for Sludge Drying

a. Monthly. Records for sludge drying to be reported on the monthly sewage log include the following:

(1) Total gallons drawn to beds.

(2) Average pH, percent solids, and percent volatile solids.

(3) Total cubic yards of sludge removed.

(4) Average drying time in days.

b. Daily. Additional bench records kept for basis of log and for plant control include the following:

(1) Date, volume in gallons, and depth in inches of sludge applied to each bed by bed number.

(2) Results of pH, percent solids, and percent volatile solids of each sludge withdrawal.

(3) Date, volume in cubic yards, and disposition of sludge removed from each bed.

105. Sludge Disposal

Only well-digested sludge, wet or dried, is used on the post. Raw sludge must be treated with lime or other chemical as described in a preceding paragraph, and buried or placed in the sanitary fill when dry. Digested sludge may be used for fertilizer or fill.

a. Fertilizing value. Sewage sludge is not high in nitrogen, phosphates, or potash content, generally having 1.5 to 4.0 percent nitrogen (as N), 1.5 to 2.5 percent phosphate (as P_2O_5), and usually no more than a trace of potash. The principal value of sewage sludge is the humus content which averages from 25 to 35 percent.

b. Use as fertilizer. Use of wet or dry digested sludge for fertilizer on Army posts is subject to the restrictions of TM 5-600. It must not be applied to crops eaten raw. The frequent presence of hookworm eggs in sludge may cause infection where climate and soil favor continued hookworm activity. Digested sludge is particularly suitable for fertilizing vegetation cultivated for dust and erosion control or for lawns, flower beds, and shrubbery.

c. Disposal of dried sludge. Unless large drying areas are available, dried sludge is removed from beds as soon as it can be handled and piled where it is accessible for grinding and/or hauling.

(1) If the sludge removed from drying beds is lumpy and difficult to spread, it can be broken up by running a tractor or other heavy equipment back and forth over the stock pile. Dried sludge may be pulverized by a mechanical grinder. (See fig. 84.) This device requires that the sludge be well digested of proper dryness. If the sludge is too dry, it flies out of the machine; if too wet, it sticks and clogs the machine.

(2) On established lawns, pulverized sludge is spread uniformly, although blanching occurs if it is allowed to blanket the grass. On areas to be seeded, the sludge is spread uniformly and worked into the soil. Records are kept of persons taking sludge off the post for fertilizer.

d. Application of wet sludge. In some instances, particularly where drying-bed facilities are deficient, well-digested sludge may be drawn into tank trucks and applied directly to areas being fertilized. Wet sludge is normally applied in quantities up to 100 gallons per 400 square feet. Lawns may be lightly sprinkled immediately after application to wash the sludge into the roots of the vegetation. Figure 85 shows a tank being loaded from the sludge-discharge line at the drying beds; figure 86, a method of gravity application; figure 87, use of a pump and spray nozzle; figure 88, post-made disk spreader.

e. Disposal of dry sludge as fill. Dry sludge may be put on dumps or in low areas. Trestles or other devices for dumping must be provided since the sludge does not support heavy hauling equipment.

f. Lagooning digested sludge. Digested sludge direct from the digesters may be discharged to lagoons instead of drying beds. The lagoons must be located in isolated areas, preferably where the sludge will flow by gravity. Figure 89 shows a typical sludge lagoon.

Section X. TRICKLING FILTERS

106. General

The trickling filter is the most common secondary-treatment unit at Army plants; it is preceded by primary settling. The filter is an artificial bed of stone or slag 3 to 8 feet deep; its holding structure is usually concrete although it may be brick, masonry, or wood. The filter has a distribution system

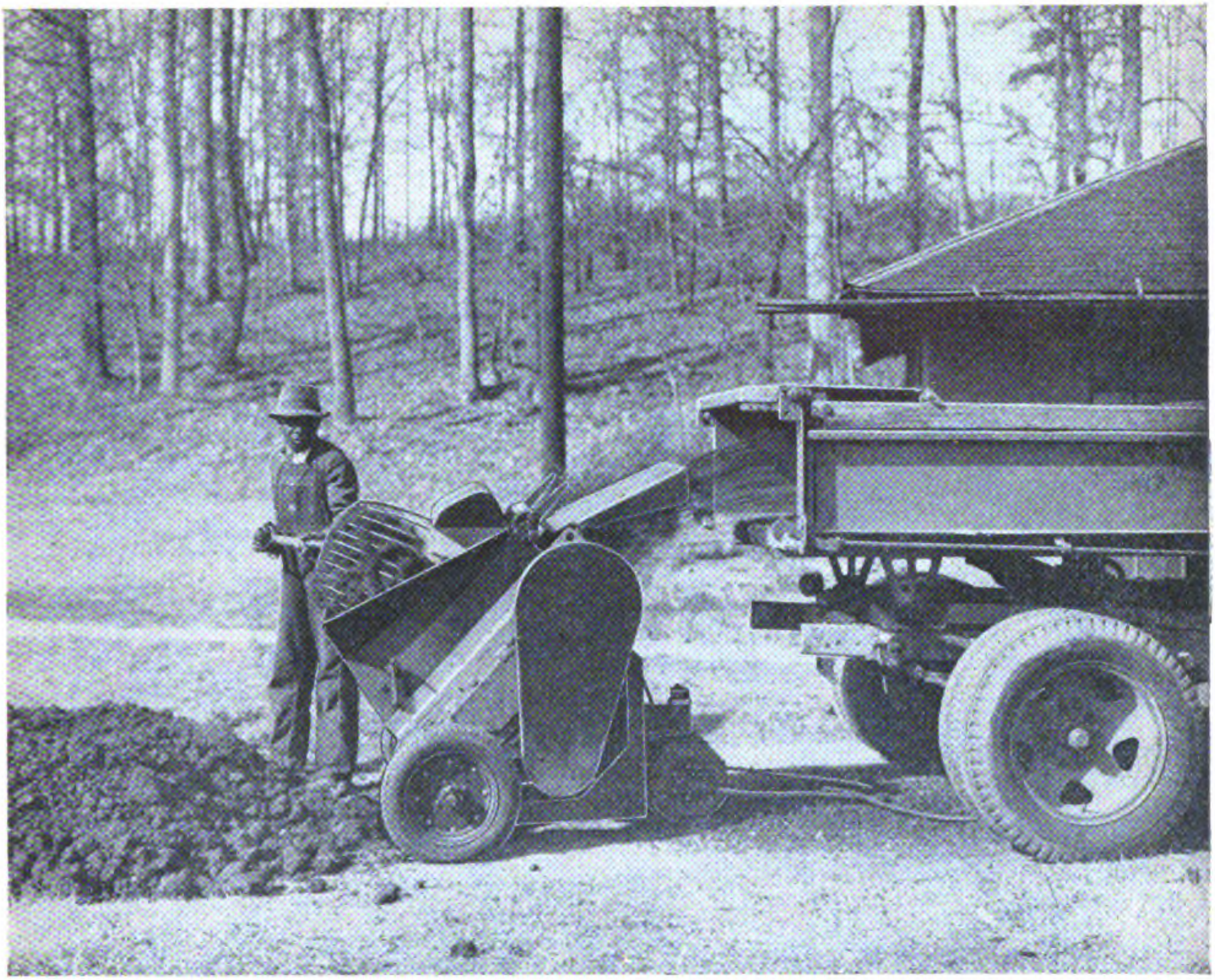


FIGURE 84. *Sludge disintegrator loading directly to truck.*

for applying settled sewage and an underdrain system to remove filter effluent and circulate air through the filter. Reaction or motor-driven rotary distributors, fixed nozzles, or disks are used to spray the influent on the bed, obtaining necessary head by a pump, constant-head box, or dosing chamber with automatic siphon. The underdrain system usually has a sloping channeled floor with slotted or open-joint vitrified-clay half tiles or blocks directly supporting the filter media. Wood-grid underdrains are also used.

a. THEORY OF OPERATION. The stone or other filter media provide a surface for developing gelatinous films or slimes containing aerobic bacteria, algae, fungi, protozoa, worms, and larvae. As the settled sewage passes through the stone, organisms flocculate much of the suspended, colloidal, and soluble material and hold it within the film. Organic and mineral matter thus removed feeds the organisms. Adequate air supply is essential for oxidation of this food. The organisms and their by-products accumulate in the film, sloughing off intermittently or continuously with the effluent. The reactions taking place are governed by the quantity and quality of the applied sewage, rate and continuity application, air supply, temperature, and other factors. These reactions differ in the two general types of filters: the standard low-capacity filter and the high-capacity filter.

b. FILTER LOADINGS. Filter loadings are based on two factors: volume of sewage applied per unit of filter surface area and quantity of BOD applied per unit of filter volume.

(1) *Volumetric loading.* Volumetric loading is expressed as millions of gallons per day per acre (mgad). To determine the vo'umetric loading, the average flow in mgd to the filter (including any re-

FIGURE 85. *Arrangement for loading tank truck.*

FIGURE 86. *Gravity application of wet sludge.*

FIGURE 87. *Pump-and-spray application of wet sludge.*

circulated effluents) is divided by the filter area in acres.

(2) *BOD loading.* BOD loading is expressed as pounds of BOD applied per day per acre-foot (acres times depth in feet). It is determined by multiplying the average BOD (in ppm) of the primary effluent by the average flow (in mgd) and by 8.34 to obtain pounds of BOD per day, and dividing this by the acre-feet. Where filter or final-tank effluents (other than normal amounts of final-tank sludge) are returned through the primary settling tank, the recirculating BOD load exaggerates the loading. In such cases, BOD loading is based upon raw sewage flow and BOD less an assumed 35 percent BOD removal in the primary-settling tank. High-capacity filter BOD loading is sometimes expressed as pounds per cubic yard. To convert to pounds per acre-foot, multiply by 1613.

c. FILTER LOADINGS BY TYPES. The following tabulation shows filter loadings by types:

Filter types	Loading	
	Volumetric mgad	BOD pounds per acre-foot
Standard rate (low capacity):		
Normal design (OCE)	Approx. 2	600
Highly loaded	2 to 10	600 to 1,500
High capacity:		
Normal design (OCE)	10 to 60*	3,000
Low loading	10 to 60	1,500 to 3,000
High loading	10 to 60*	3,000 to 5,000
Roughing (followed by additional secondary treatment).	10 to 60*	3,000 to 12,000

* May be above 100 mgad in some cases.

d. FACTORS AFFECTING OPERATION. Important factors affecting filter-operation efficiency where maximum loadings are not exceeded include distribution, ventilation, size of filter media, and temperature.

(1) *Distribution.* Uniform distribution of sewage on the filter surface is necessary for effective utilization of all the filter capacity. Uniformity with fixed-nozzle distribution is provided by proper design of the dosing chamber. As the head

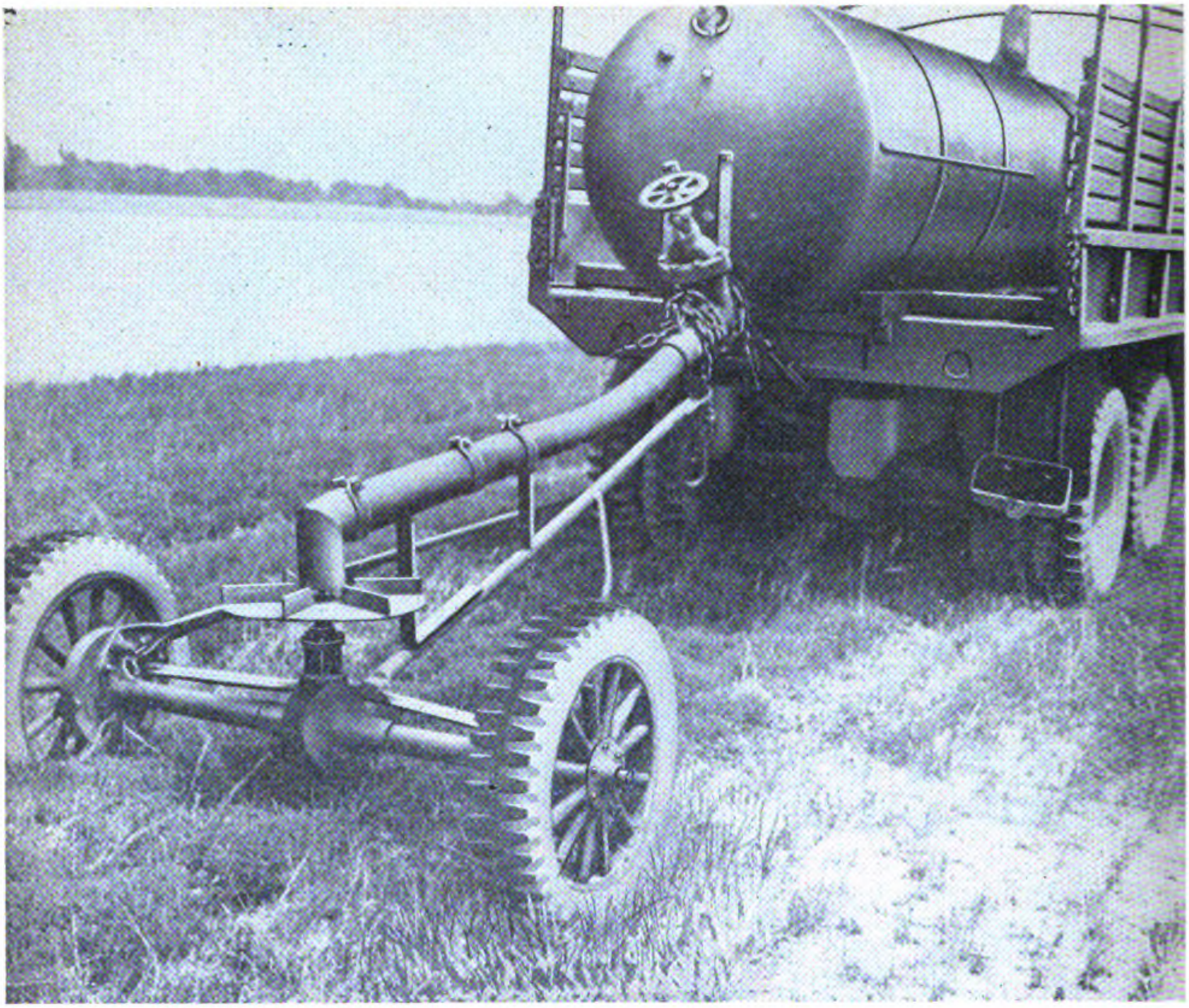


FIGURE 88. *Disk distributor for applying wet sludge.*

decreases, the circle of application becomes smaller. Rotary distributors have a larger number of orifices or nozzles at the outer ends of the arms than the inner to cover the increased concentric arc. Revolving-disk distributors have vanes of several sizes to give uniform application over circular filters of a 35-foot maximum diameter. Nozzles, orifices, and disks must be kept free of obstruction and grease coating. Uniformity is noted daily by visual inspection. When necessary, accurate determination is made by placing pans at representative points on the filter surface and measuring depth of sewage collected in a given time.

(2) *Ventilation.* Natural ventilation through the filter is caused by the temperature difference of the air and the sewage, upwards in cold weather and downwards in warm weather. Filter underdrains must be ample in size and free of interior and exterior obstruction. Voids between the stone must be open to provide air circulation throughout. Forced ventilation by blowers is sometimes provided. Relative amount and direction of air circulation can be observed by the use of smoke.

(3) *Media.* The filter media must be hard, clean stone 2 to 4 inches in size; it must be uniform in size through the filter.

(4) *Temperature.* Best results are obtained during warm weather. Winter conditions in northern climates may reduce filter efficiency 50 percent below summer operation.

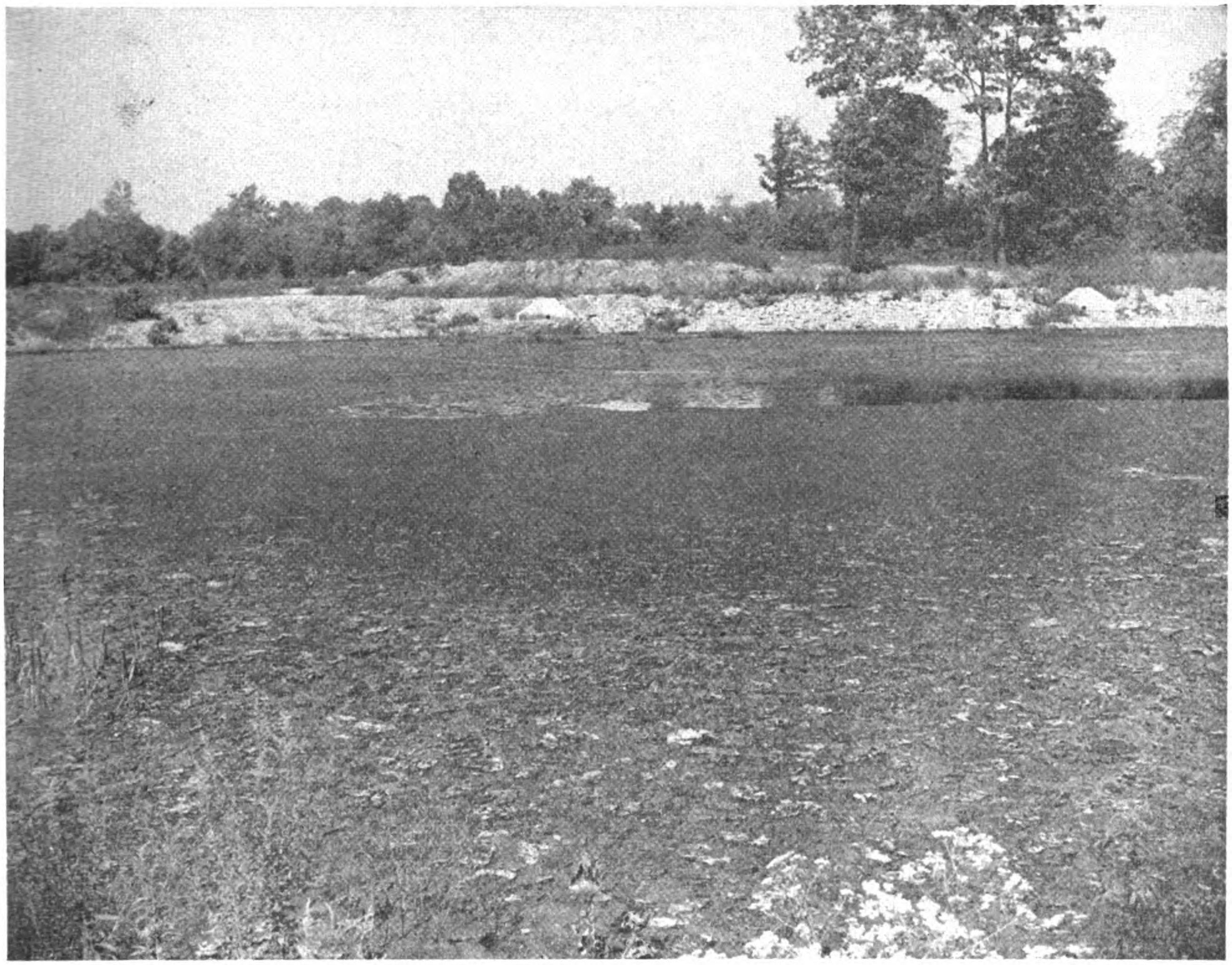


FIGURE 89. *Sludge lagoon.*

107. Standard (Low-capacity) Filters

Standard filters are either rectangular with fixed nozzles (fig. 90) or circular with rotary distributors (fig. 91). Intermittent dosing is provided for both types by a dosing tank which automatic siphon (fig. 92) or by direct pumping. Filter depths vary from 6 to 8 feet.

a. NATURE OF BIOLOGICAL ACTION. In well-ventilated, deep, standard filters, two zones of activity are apparent. Organisms predominate in the top of the filter which break down proteins and amino acids into ammonia and simpler sulfur compounds and decompose carbohydrates to acids. At the lower levels, organisms oxidize ammonia and sulfur compounds to nitrites and stable nitrates and sulfates.

b. UNLOADING. A relatively thick growth developes in the standard filter during normal operation until a temperature change or flow of influent through the bed causes a large portion to slough off. This slough, usually occuring in the fall and spring, makes the filter effluent quite turbid and frequently contains large masses of worms normally present in the filter. These solids are removed in the final-settling tank.

c. PONDING. If the primary effluent is poor in quality and high in suspended-solids or grease content, if the filter has poor ventilation, or if the stones are small or improperly cleaned or graded, growths may develop at the surface of the stone which stop the flow through the bed. Corrective measures for this ponding are discussed in paragraph 109.

d. INSECTS. A small mothlike fly, *Psychoda*, frequently infests the standard filter. It can pass through ordinary window screens, becoming a nuisance by getting into the eyes, ears, nostrils, and mouths of plant operators. Its natural flight range

is only a few hundred feet unless carried farther by wind; the life cycle varies from 22 days at 60° F. or 7 days at 85° F. Heavy infestation comes with thick growth on the stones and high temperatures. The water spring-tail, which may occur in trickling filters, feeds upon the organic growths on the exposed bed surface and helps keep it clean.

e. PERFORMANCE. The efficiency of BOD removal of a plant using primary settling, standard filters with BOD loading of 600 pounds per acre per

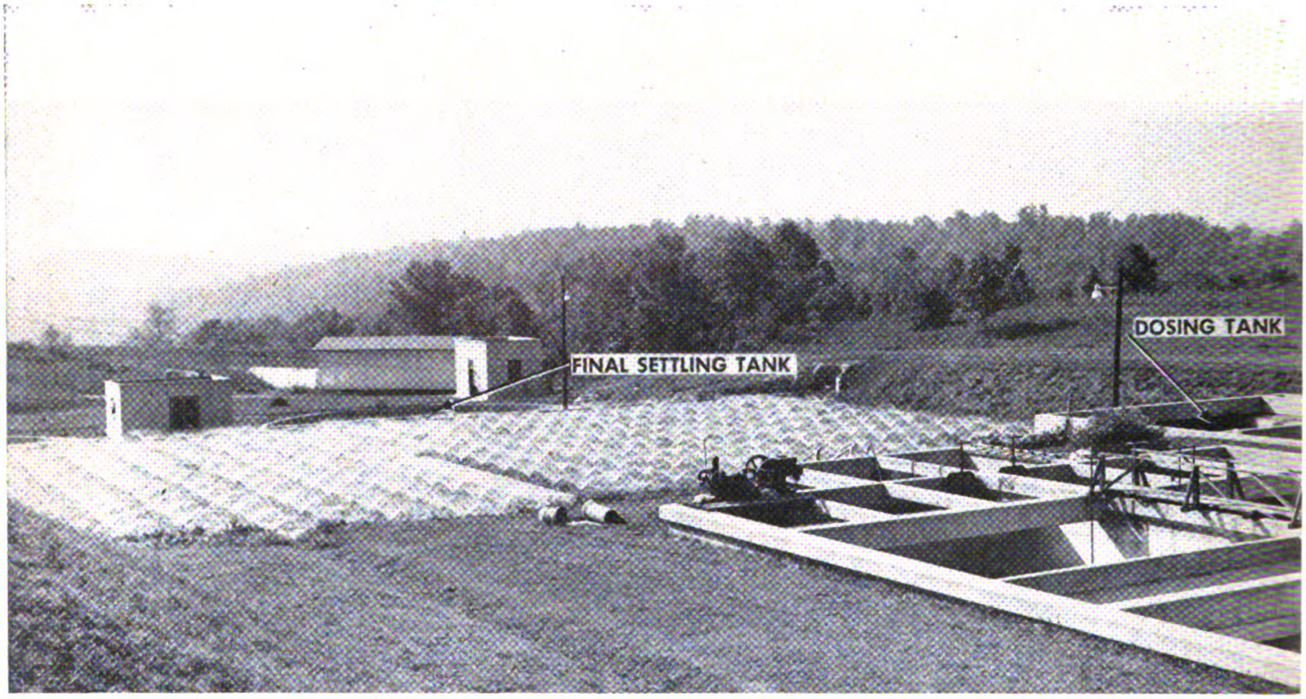


FIGURE 90. *Trickling filter with fixed nozzles.*

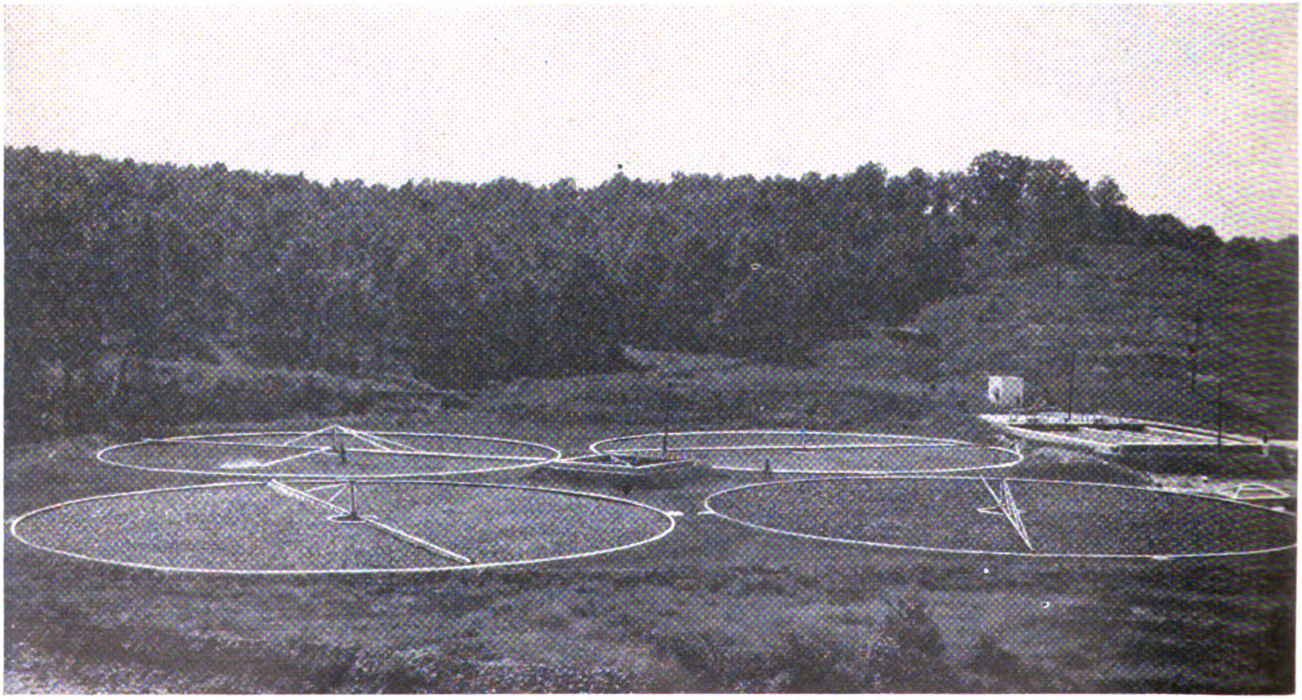


FIGURE 91. *Standard filter with rotary distributors.*

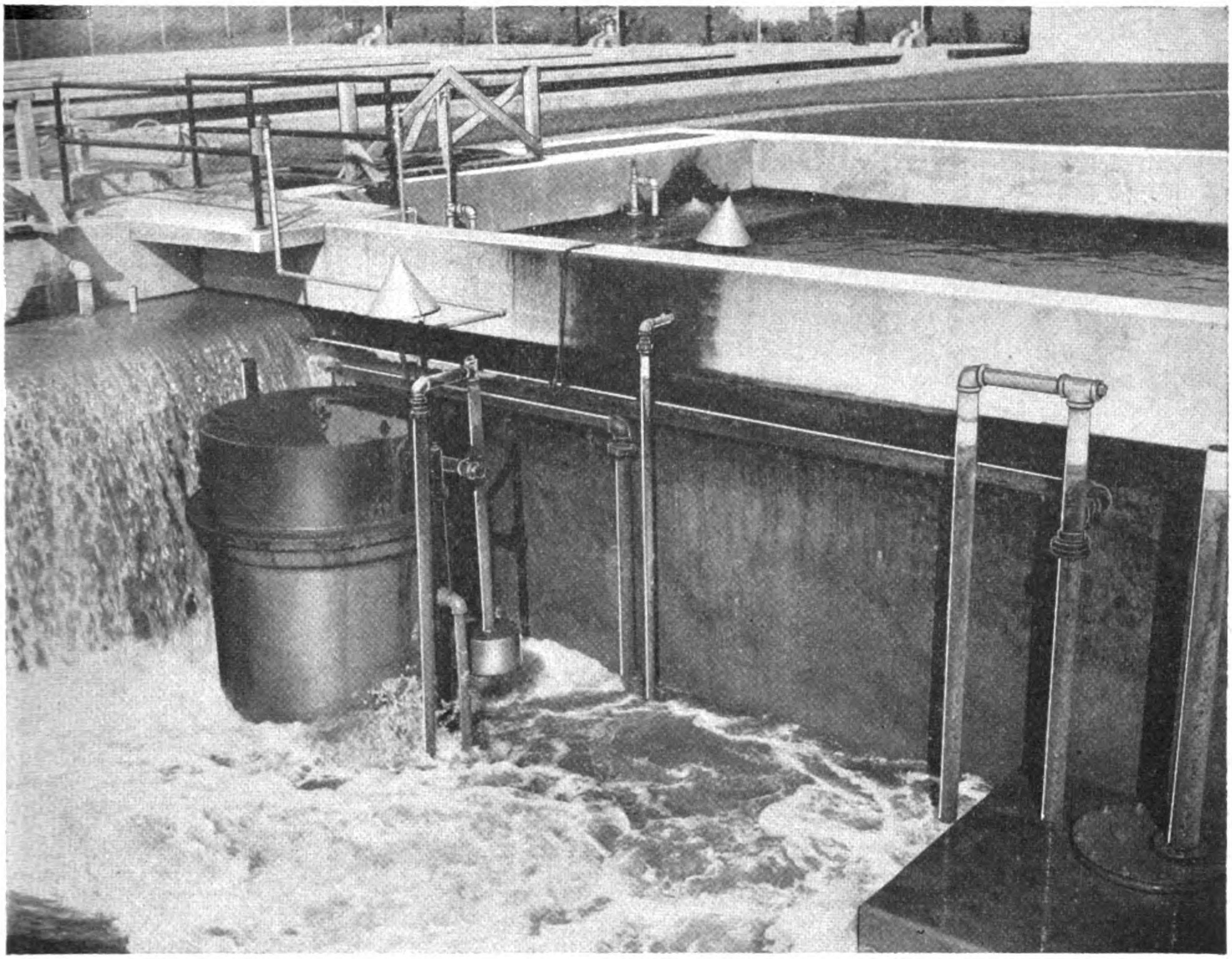


FIGURE 92. *Dosing tank.*

foot, and final settling should be 80 to 90 percent. Final effluent normally has BOD and suspended-solids contents of 30 ppm or less, and is nitrified enough to show a methylene blue relative stability of 90 to 99 percent. In the relative-stability test (par. 162), the oxygen demand of the effluent is supplied not only by the available dissolved oxygen, as in the BOD test, but also by the reduction of nitrates and nitrites. The methylene blue dye becomes colorless when these oxidizing compounds are depleted. In the absence of nitrogen determinations, the test provides a good index of nitrification.

108. High-capacity Filters

High-capacity filters are usually circular, varying from 3 to 8 feet deep. A few rectangular high-capacity filters with special fixed nozzles have been constructed at Army posts. The filter media, 3- to 4½-inch size, are usually larger than in low-capacity filters to pass a greater sewage flow. The underdrain systems are usually designed to flow only one-third full under maximum operating conditions to insure adequate ventilation.

a. NATURE OF OPERATION. The high-capacity filter has a continuous high-rate sewage application, well distributed over the bed surface. High rate of application is done by recirculating sewage already passed through the filter, either continuously or during low raw-sewage flow. The heavy flow of sewage over the biological growth produces continuous, instead of periodic, sloughing as in the standard filter. Since solids are not retained in the filter for long periods as in the standard filter, they are less stable and continue to exert a considerable oxygen demand in settling tanks receiving filter effluent. Likewise, the solids continue sewage clarification and BOD removal in the settling tanks

as long as aerobic conditions are maintained. The settling tanks, including primary tanks if filter effluent is returned through them, are integral parts of high-capacity filter treatment. Nitrification is negligible with BOD loading in excess of 2,000 pounds per acre-foot.

b. Aero-filter. The aero-filter is a patented high-capacity filter process providing continuous, uniform sewage distribution over the entire surface. A deep filter (5 to 8 feet) is used. Recirculation is usually used only during low-flow periods to maintain the minimum rate of application; disk or rotary type distributors are used. The rotary distributor has 4 to 10 branched arms and revolves quite rapidly. (See fig. 93.) Special nozzles discharge sewage in a rainlike spray, giving continuous dosage to all parts of the filter surface. If blowers are provided to force air through the filter, all openings to air at the filter base must be sealed and blower operation must be continuous. A dosage rate in excess of 10 mgad of surface per day is maintained on these filters. Figure 94 shows a typical lay-out of an aero-filter.

c. Biofilter. The biofilter is a patented high-capacity filter process providing continuous recirculation and high-rate application to shallow (3 to 5

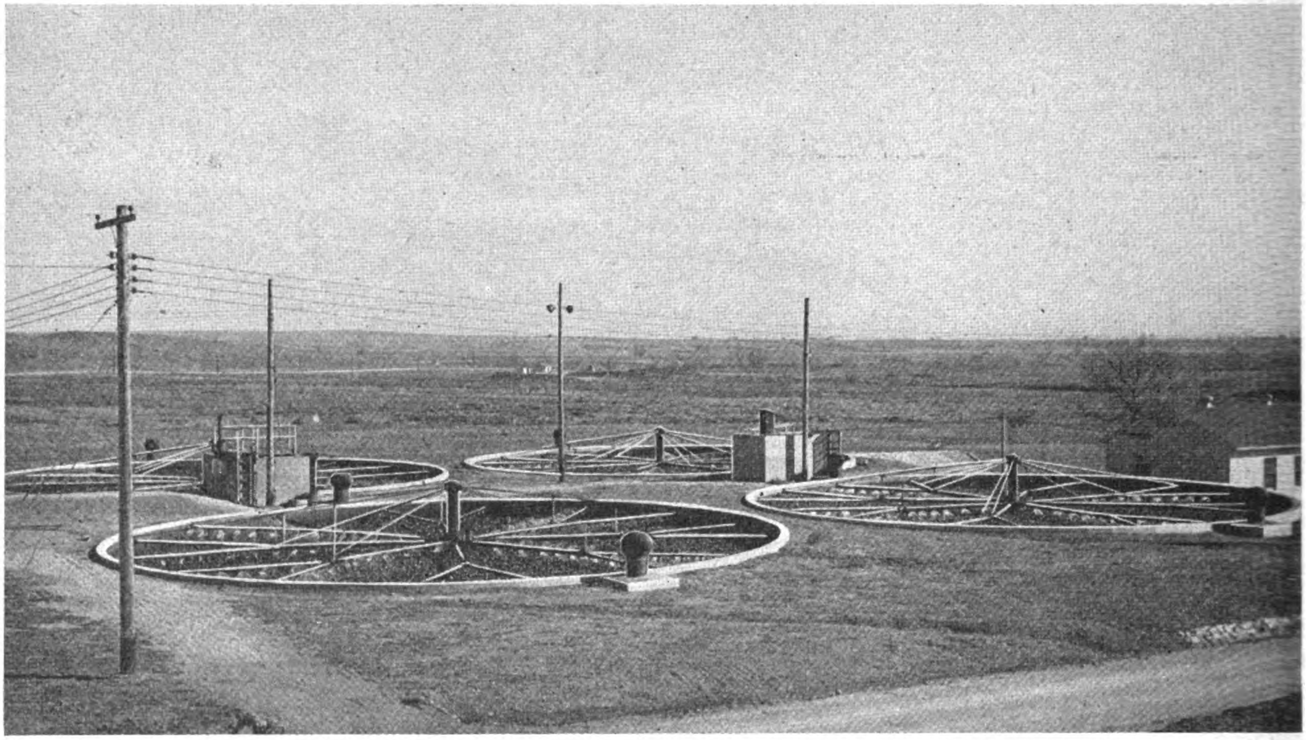


Figure 93. *Single-stage aero-filter.*

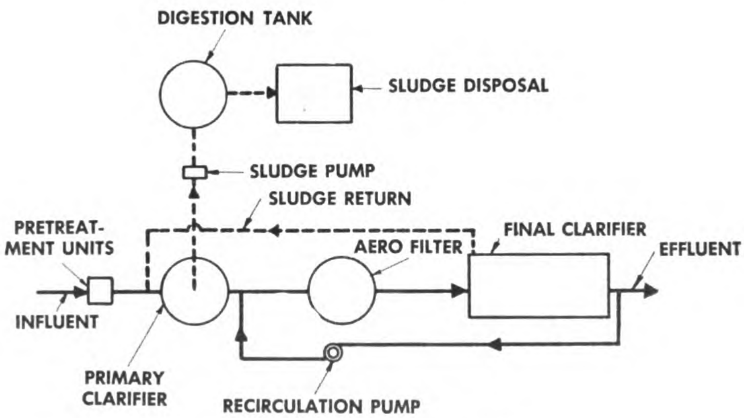


Figure 94. *Single-stage aero-filter.*

feet) filters. The settling tanks must be large enough to provide adequate settling time (par. 73) for the total flow of sewage and recirculated effluents. Figure 95 shows a single-stage (one filter and two clarifiers) dual-recirculation filter. Figure 96 shows a two-stage (two filters and two clarifiers) filter with the filter effluents recirculated to the respective clarifiers; figure 97 shows the same type with a modified recirculation. Figure 98 is an aerial view of a typical plant showing biofilters, two-stage digesters, sludge-drying beds, and primary- and final-settling tanks. Many different arrangements for circulating effluents are used, involving single-stage or multistage (usually two-stage) filtration. Most of these arrangements are shown in figure 99.

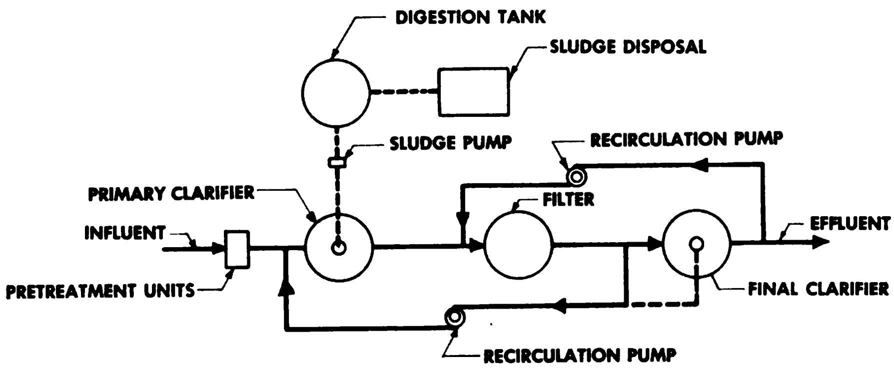


FIGURE 95. *High-capacity single-stage filter.*

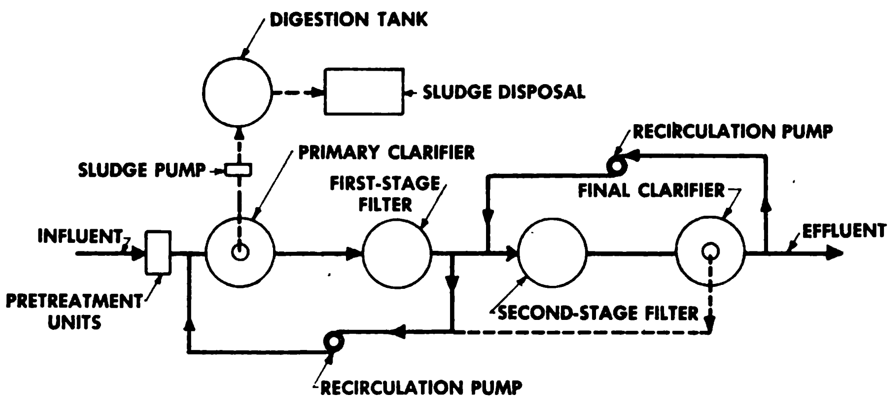


FIGURE 96. *High-capacity two-stage type.*

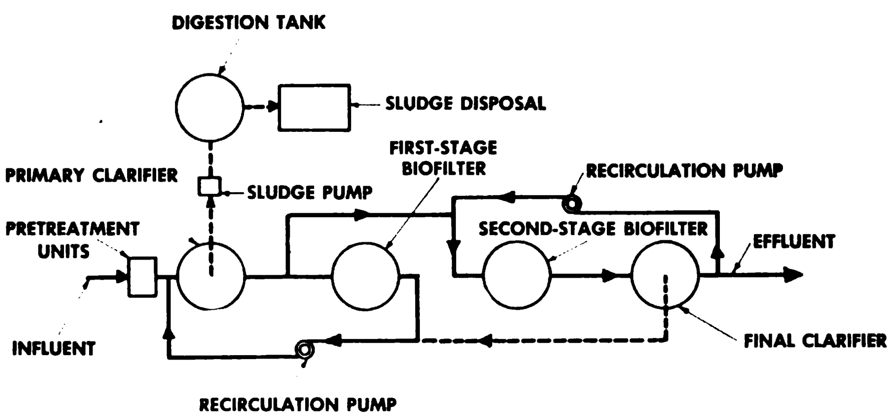


FIGURE 97. *High-capacity two-stage filter (modified).*

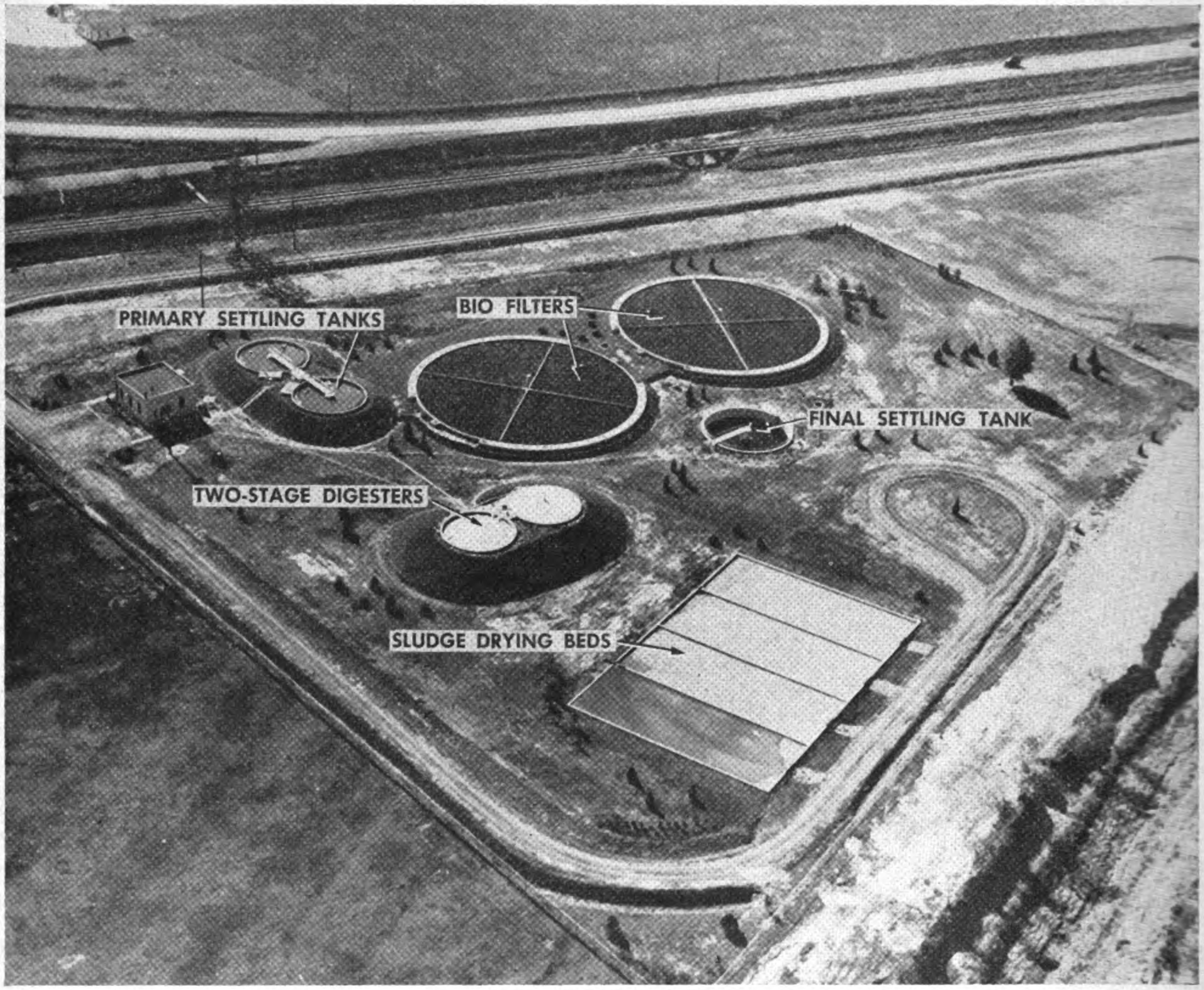


FIGURE 98. *Aerial view of two-stage biofilter plant.*

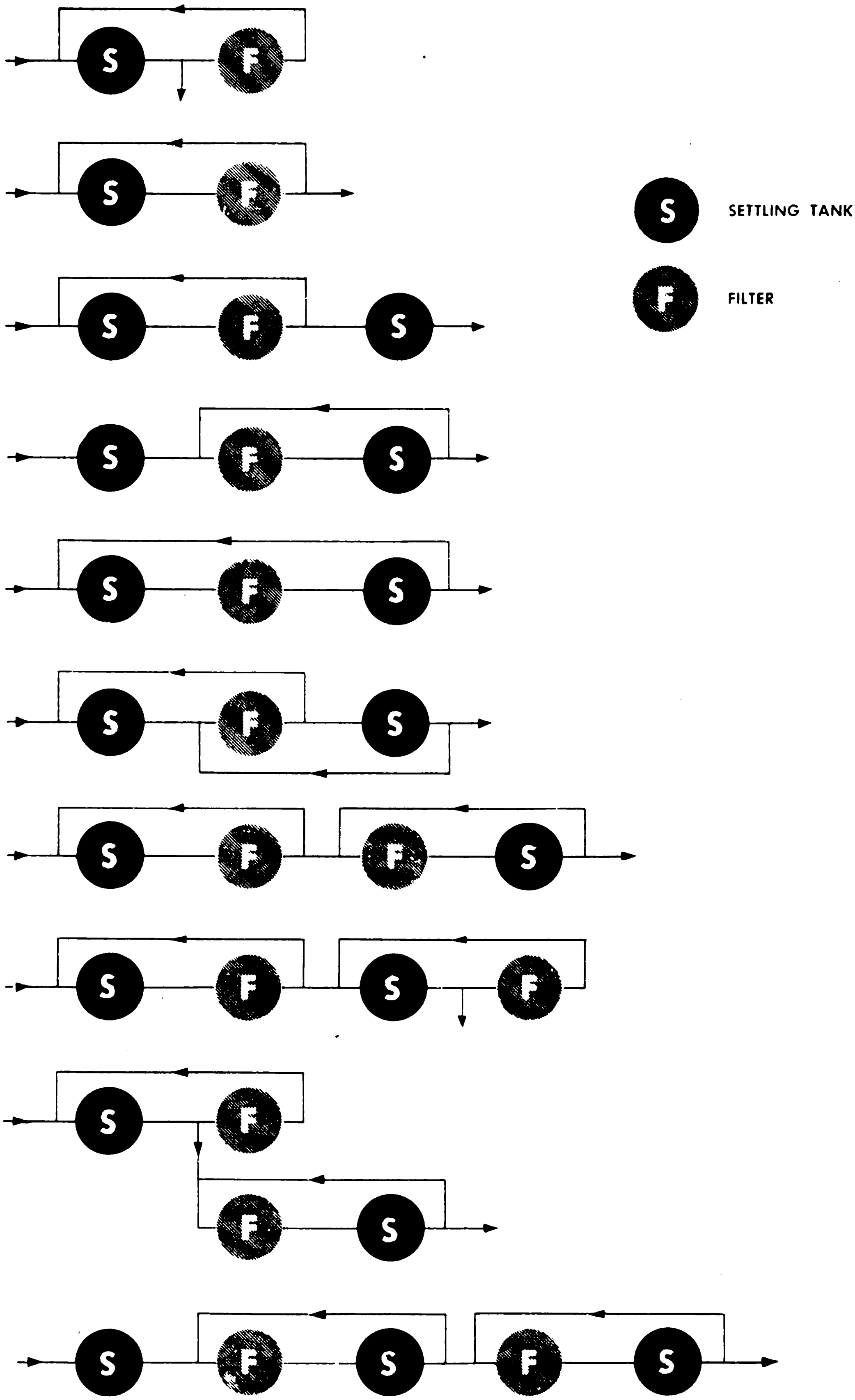


FIGURE 99. *Arrangements for recirculation in high-capacity filter plants.*

d. Accelo-filter. The accelo-filter, another patented process (fig. 100), recirculates filter effluent to the filter influent. The returned sludge seeds the filter.

e. Combined high and low capacity. Excellent results are obtained by using a high-capacity or roughing filter followed by an intermediate-settling tank, a low-capacity filter, and a final-settling tank. BOD loadings on these roughing filters range from 3,000 to 12,000 pounds per acre-foot per day. The low-capacity filter has a normal load. Continuous flow is maintained by recirculation.

f. Performance. The high-capacity filter with 3,000 pound BOD loading usually gives over-all plant BOD removal of 75 to 85 percent. The effluent normally has a BOD from 30 to 60 ppm. Very little nitrate is produced and methylene blue relative stability seldom exceeds 50 percent. Higher removal and nitrification may be obtained at lower loadings.

109. Operation of Filters and Appurtenances

TM 5–666 covers preventive maintenance of siphons and distributors.

a. Siphons. Siphons provide intermittent dosing of sewage to filters. Figure 101 shows a siphon in a dosing tank.

(1) In starting the main trap and the blow-off trap of siphons, fill them with water. Then admit sewage flow to dosing tank.

(2) Adjust discharge elevation as needed for proper filter distribution by raising or lowering the blow-off trap piping.

(3) Clean dosing chambers at least once each week by stirring bottom of tank. Remove grease and slime adhering to walls and piping daily.

b. Distributors and spray nozzles. (1) Remove all scum and growths from rotary distributors weekly. Inspect and clean each orifice daily. Open gates at the ends of the arms to remove accumulated material by flushing through the arms.

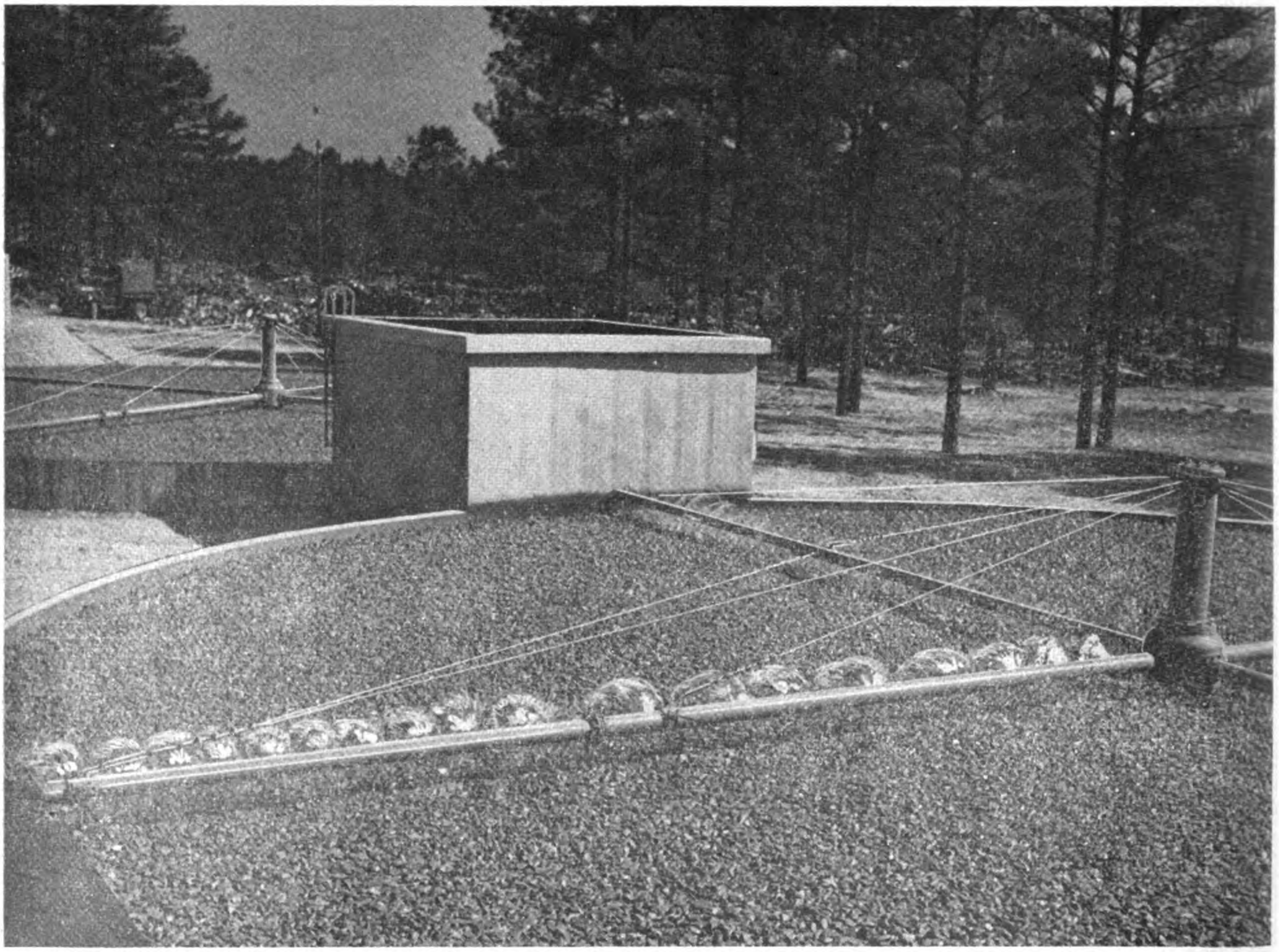


Figure 100. *Accelo-filter installation. Note constant-head dosing box.*

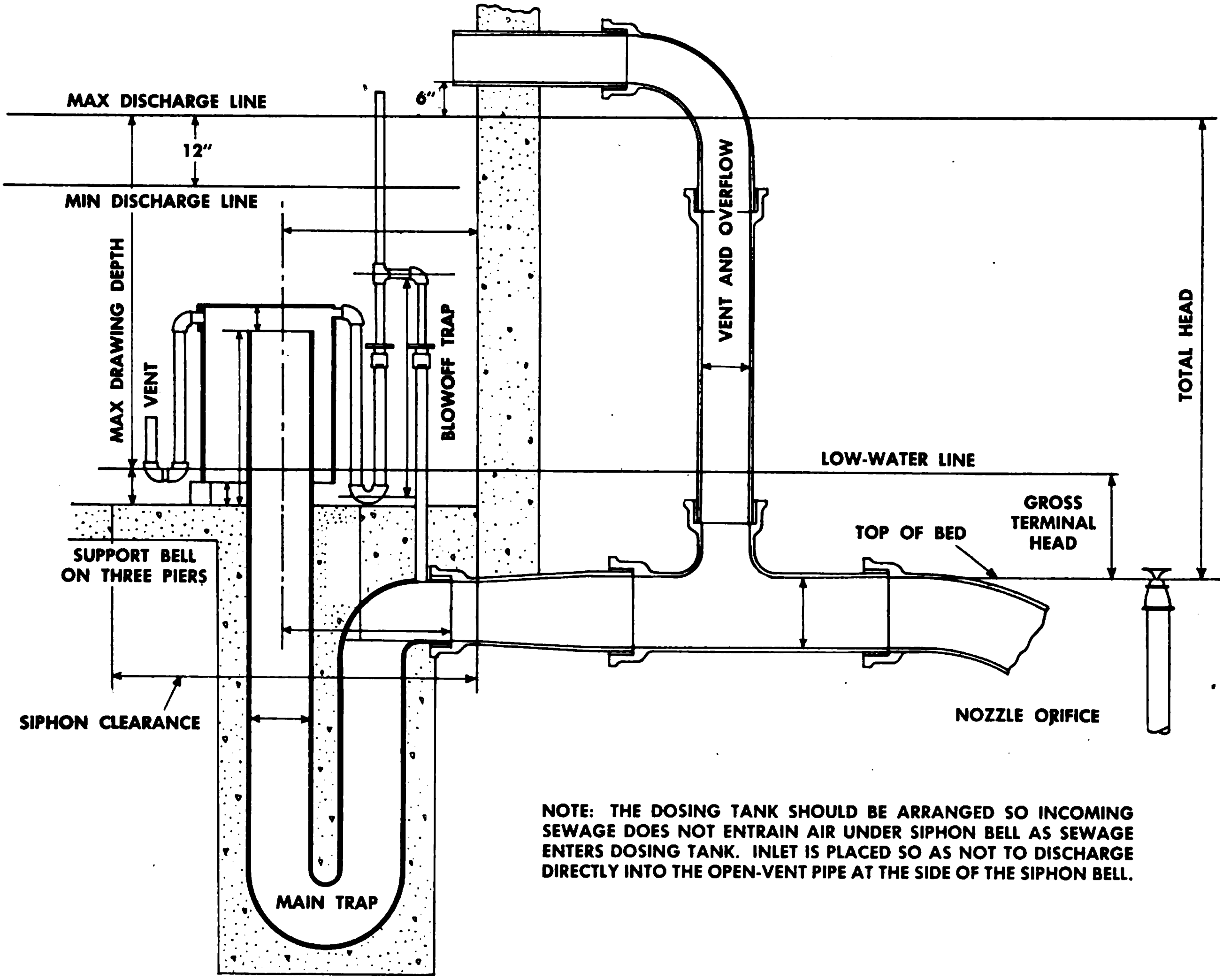


FIGURE 101. *Deep-seal siphon on dosing tank.*

(2) Inspect fixed nozzles on trickling filters daily, removing all growths and other material. Remove nozzles on the ends of the laterals for a few minutes daily and flush sewage through the lines to remove any accumulations.

c. FILTER STONE. (1) During winter operation in northern climates, keep filter surface sufficiently free of snow to permit operation of rotary distributor.

(2) Keep filter surface free of leaves. Remove nearby trees if necessary.

(3) If small particles of rock or sand are washed out of the filter, remove them from the collection channels manually to prevent their discharge to settling tanks. If this material reaches the digester, it may plug sludge lines and reduce digester capacity. Figure 102 shows an improvised grit chamber for removal of this material.

(4) At high rates of application, prevent spray over the outer walls by shields which direct spray back to filter bed. Figure 103 shows a post-made shield for this purpose.

d. PONDING OF FILTERS. Ponding of filters may occur, if prolific fungus growths completely fill the voids between the rocks. Such growths may develop if the filter stone is too small or broken, if the filter is heavily loaded, or if wastes containing large amounts of carbohydrates are treated. Excessive grease may plug the filter. The following may reduce ponding:

(1) Flush the filter surface with a fire hose.

(2) Rake or fork the surface.

(3) Stop distributor over the affected area allowing continuous flow to wash down the growth.

(4) Punch holes through top layer of filter rock with iron bar or pick.

(5) Add heavy applications of chlorine or chlorinated lime up to 5 ppm residual to filter influent for 2 to 4 hours at weekly intervals. To conserve

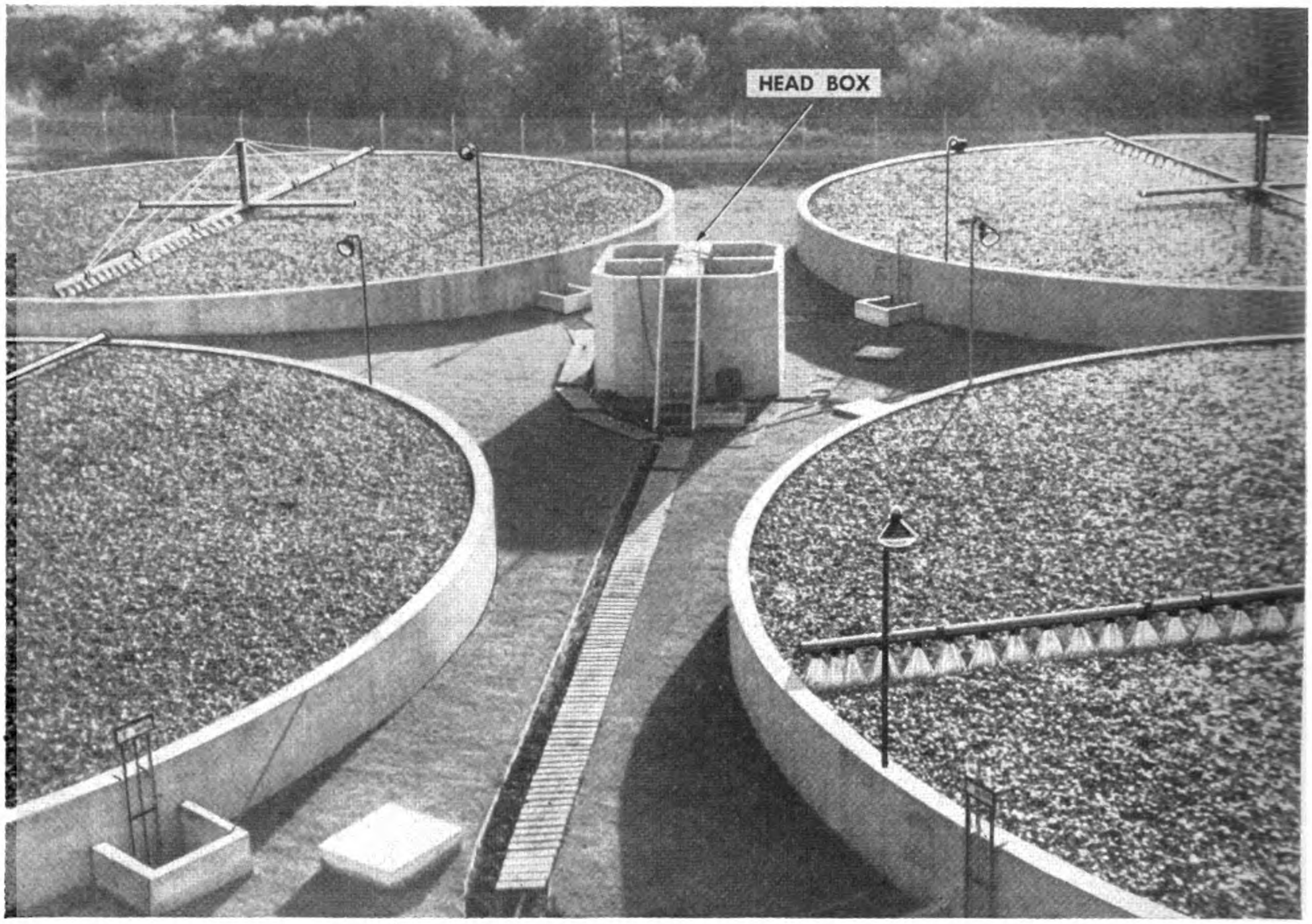


FIGURE 102. *Improvised grit chamber for filter effluent.*

chlorine, do this at night when sewage flow and chlorine demand is low. (See par. 142.)

(6) Flood the filter if possible.

(7) Allow the growth to dry by taking filter out of service for 12 to 48 hours. Try this only if other adequate units are available.

(8) Never use heavy equipment to plow filter surface because the weight damages walls, rock, and underdrain system.

(9) If all other methods fail, remove stone and replace with a larger size.

e. CONTROL OF FILTER FLIES. Filter flies in the larval stage assist in biological action. Breeding in filters is minimized considerably by continuous application of influent at a high rate and if stone and wall surfaces are always wet. Filter flies prefer alternate wet and dry environment. Pupae and larvae developing under such conditions are continuously washed to the final settling tank where they may have to be skimmed from the surface. On the standard filter, particularly with intermittent operation, psychoda flies may become a nuisance. The following control methods are used if the nuisance becomes serious:

(1) Reduce food supply and film development by removing excessive growths as shown above.

(2) Hose inside of filter walls vigorously.

(3) Flood filter for about 12 hours every 2 weeks.

(4) Use chlorine (par. 142) or such chemicals as DDT or dichlorobenzene as prescribed by higher technical authority.

f. CONTROL OF ODOR. Odors from sewage, caused by anerobic decomposition of organic matter, may be eliminated by the following methods:

(1) Where sewage decomposes before reaching the plant in extensive systems or systems with flat grades, keep sewers clean and apply copper sulfate or chlorine in the upper part of the system if necessary in accordance with paragraph 30.

(2) Excessive detention of sewage in tanks may permit decomposition; the detention period should not exceed 3 hours in the primary tanks. Remove tanks from service to reduce detention time if practicable.

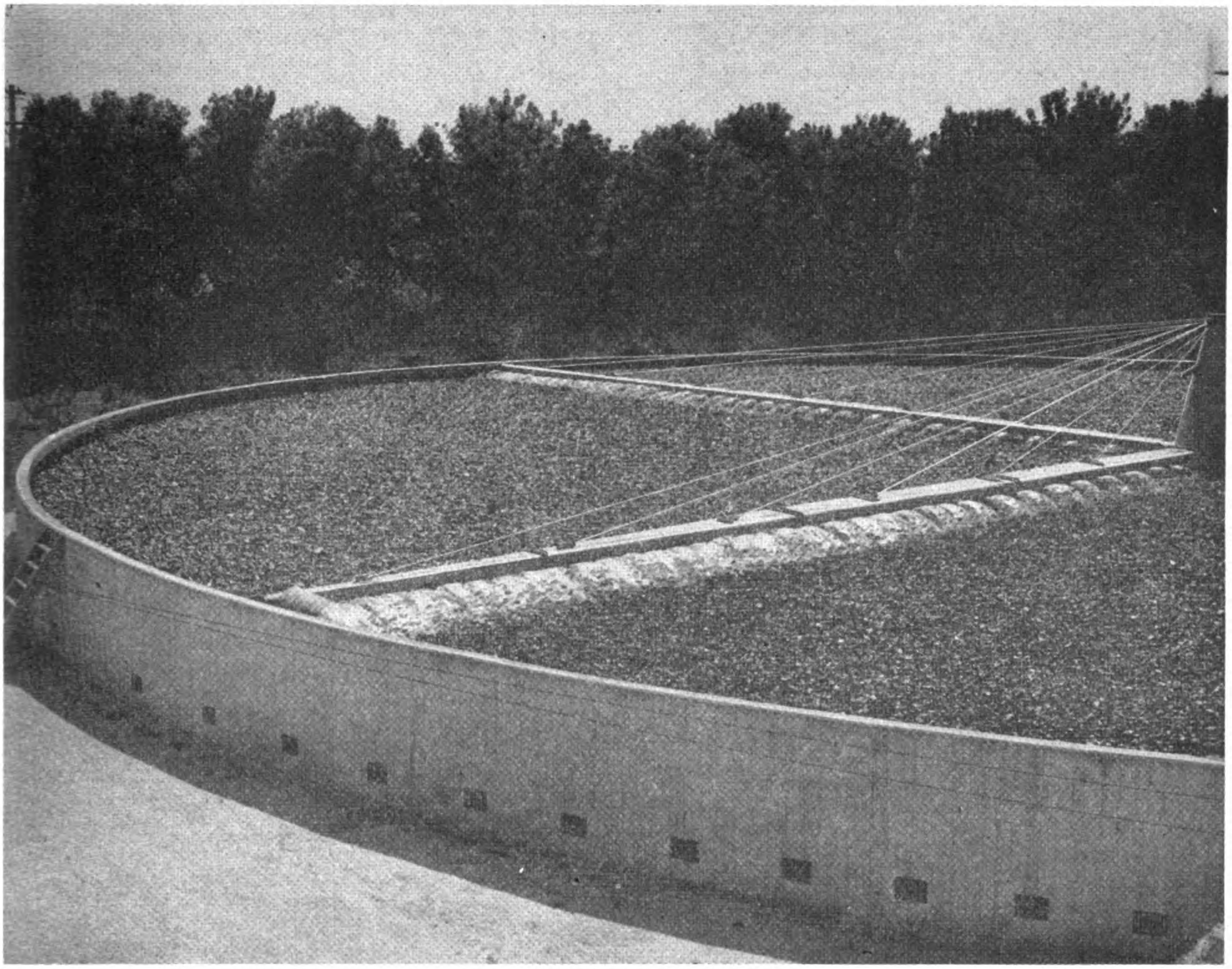


FIGURE 103. *High-capacity filter showing shield on arm.*

(3) Recirculate effluent to add dissolved oxygen to the sewage, reduce tank detentions, and dilute the sewage.

(4) Use partial chlorination of filter influent up to 5 ppm dosage. (See par. 141.)

g. INTERMEDIATE AND FINAL-SETTLING TANKS. Paragraphs 74 and 75 contain more complete operating instructions for intermediate and final-settling tanks; TM 5–661 covers preventive maintenance of sludge-collection mechanism.

(1) *Detention time.* Where final effluent is recirculated, take excessive units out of service if practicable to keep detention time below 2½ hours.

(2) *Sludge removal.* (*a*) *Standard filters.* Remove sludge from settling tanks following standard filters frequently enough to prevent rising sludge. Once daily may be enough in cold weather if sludge is stable. Denitrification may occur in warm weather, causing release of nitrogen gas and rising sludge. Sludge removal every 3 hours may be necessary for control of rising sludge and during the filter sloughing period.

(*b*) *High-capacity filters.* Remove sludge from settling tanks following high-capacity filters at least once each shift or oftener as required. This sludge becomes septic much more rapidly than that from standard filters. If centrifugal pumps are used, recirculation from the bottom of the tanks may be done to give continuous removal.

(3) *Sludge disposition.* Return intermediate- and final-tank sludge to the raw sewage for concentration with the raw sludge. Direct pumping to digester is done only where special means are provided for sludge concentration. The normal high water content upsets digester operation.

h. RECIRCULATION. The amount of recirculation for any particular filtration process depends upon a number of factors.

(1) Sizes of pumps, distributors, and settling units impose limits.

(2) Power utilization and cost must be considered.

(3) Treatment must avoid creation of a nuisance, prevent harmful effects on the receiving stream or land, and meet public health requirements.

(4) Enough recirculation to prevent septic contions caused by long detention periods at low flows and prevent drying of filter beds is desirable.

(5) Recirculation is sometimes required to provide uniform rates of application.

(6) Recirculation affects continuous unloading of filter growth, lessens fly breeding, reduces strength of applied sewage, helps prevent odors, and provides organisms for seeding filter media.

(7) Experience is necessary to determine effective method and rate of recirculation. The best guide is recirculation in sufficient amount to provide 1 ppm *minimum* dissolved oxygen in the settling tanks receiving recirculated effluent. Control samples are taken in the inside of the effluent weir. Since several weeks are needed for the filter to adjust to changes, each trial must be continued with appropriate tests for 1 month before any conclusions are made, unless failure becomes obvious.

110. Records and Reports

a. Monthly. The following data are entered on the monthly operating logs:

(1) Total quantity recirculated and points of intake and discharge.

(2) Dissolved oxygen, final effluent.

(3) Relative stability, final effluent.

(4) BOD and suspended solids, filter and final effluents.

(5) Remarks on unusual operation including ponding, heavy fly breeding, odor control, and chlorine application.

b. Daily. In addition to data required for the monthly report, the following daily records are kept:

(1) Cleaning of spray or distributor nozzles.

(2) Cleaning of siphon and dosing chamber.

(3) Dissolved oxygen of filter effluent as needed for control.

Section XI. ACTIVATED SLUDGE

111. Process

The activated-sludge process is a secondary treatment for removing dissolved or fine organic matter from sewage and changing it to more stable substances; it includes development of the active sludge, its control, and its use as a purifying agent.

a. Biological action. When sewage is agitated continuously in the presence of oxygen, an active biological material, known as activated sludge, is developed. This brownish floclike substance is composed of numerous organisms, including protozoa, in a mixture of organic solids in various stages of decomposition. Activated sludge absorbs dissolved organic material, including ammonia; it has an agglutinating or flocculating property which frees sewage from its dissolved and suspended impurities. Some materials in sewage are consumed by the organism but their most important function may be the production of complex chemical substances called enzymes which react rapidly to change objectionable matter to stable substances.

b. Flow. A flow diagram of the activated-sludge process is shown in figure 104. After receiving primary settling, sewage is mixed with

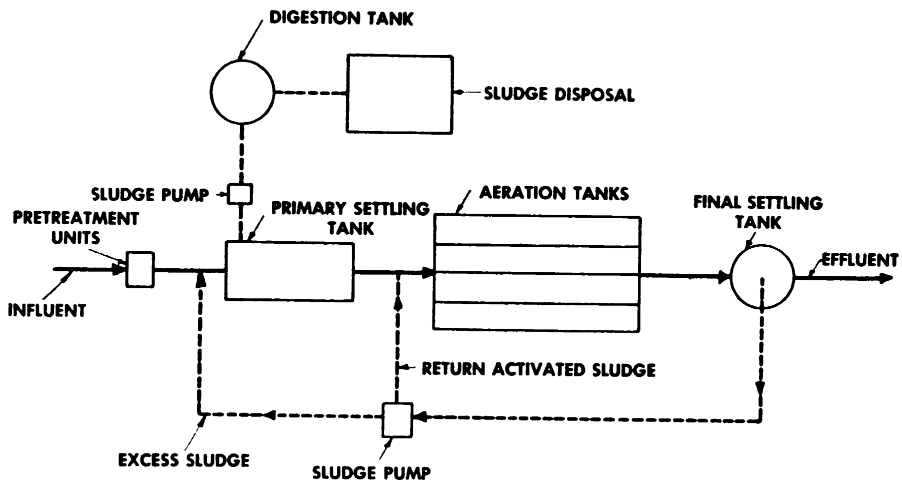


Figure 104. *Diagram of activated-sludge process.*

activated sludge to form mixed liquor. The mixed liquor then receives prolonged aeration in an aeration tank and is conveyed to the final-settling tank from which clear supernatant liquid is usually discharged without further treatment. The sludge collected at the tank's bottom is returned, all or in part, to the influent end of the aeration tank and mixed with incoming settled sewage to continue the purification process. Excess sludge is usually pumped to the plant influent and is resettled with the primary sludge to concentrate it.

112. Types of Aerators

a. Diffused-air type. Compressed air is admitted to the aeration tank through diffuser plates or tubes. About 95 to 98 percent of the air keeps the contents in motion, mixing and agglomerating the solids; the rest is used for oxidation. Diffuser equipment is usually located to provide a spiral motion to the mixed liquor. Figure 105 shows an installation of diffuser plates; figure 106 shows tanks for diffused-air aeration and the spiral motion of the sewage; figure 107 shows the swing type diffuser.

b. Mechanical. Mechanical aerators use impellers, revolving disks, or brushes for spraying sewage into the air or pulling air down into the sewage.

(1) Figure 108 shows equipment for pulling sewage up through a cone from the bottom of the tank and spraying it into the air. This is done by the motion of the impeller in the upper portion of the cone. Air mixed with the spray is carried downward into the tank.

(2) Figure 109 illustrates another mechanical aerator which forces sewage downward in a draft tube. Air mixed with the sewage at the funnel of the tube is pulled downward and rises from the tank bottom through the sewage.

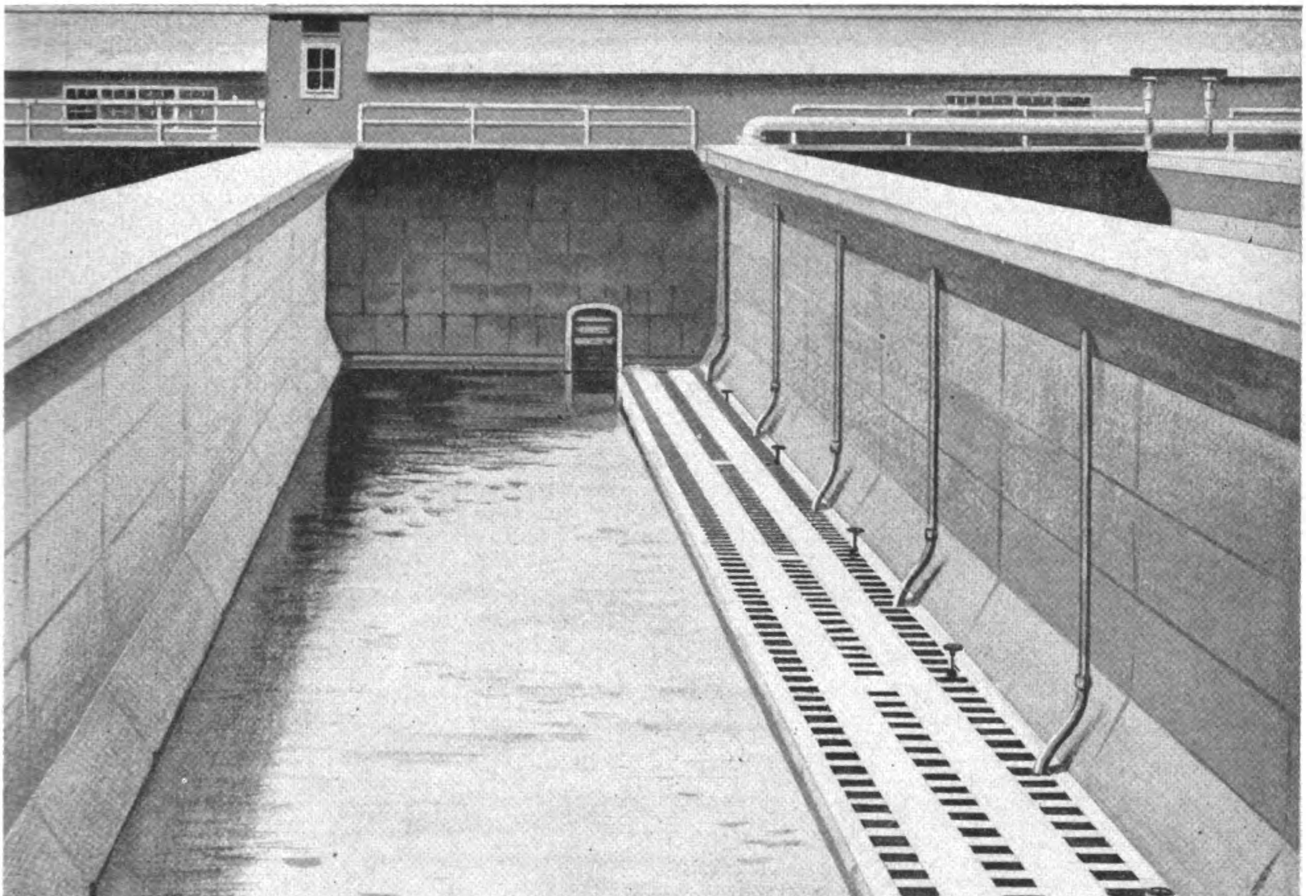


Figure 105. *Aeration by diffuser plates.*

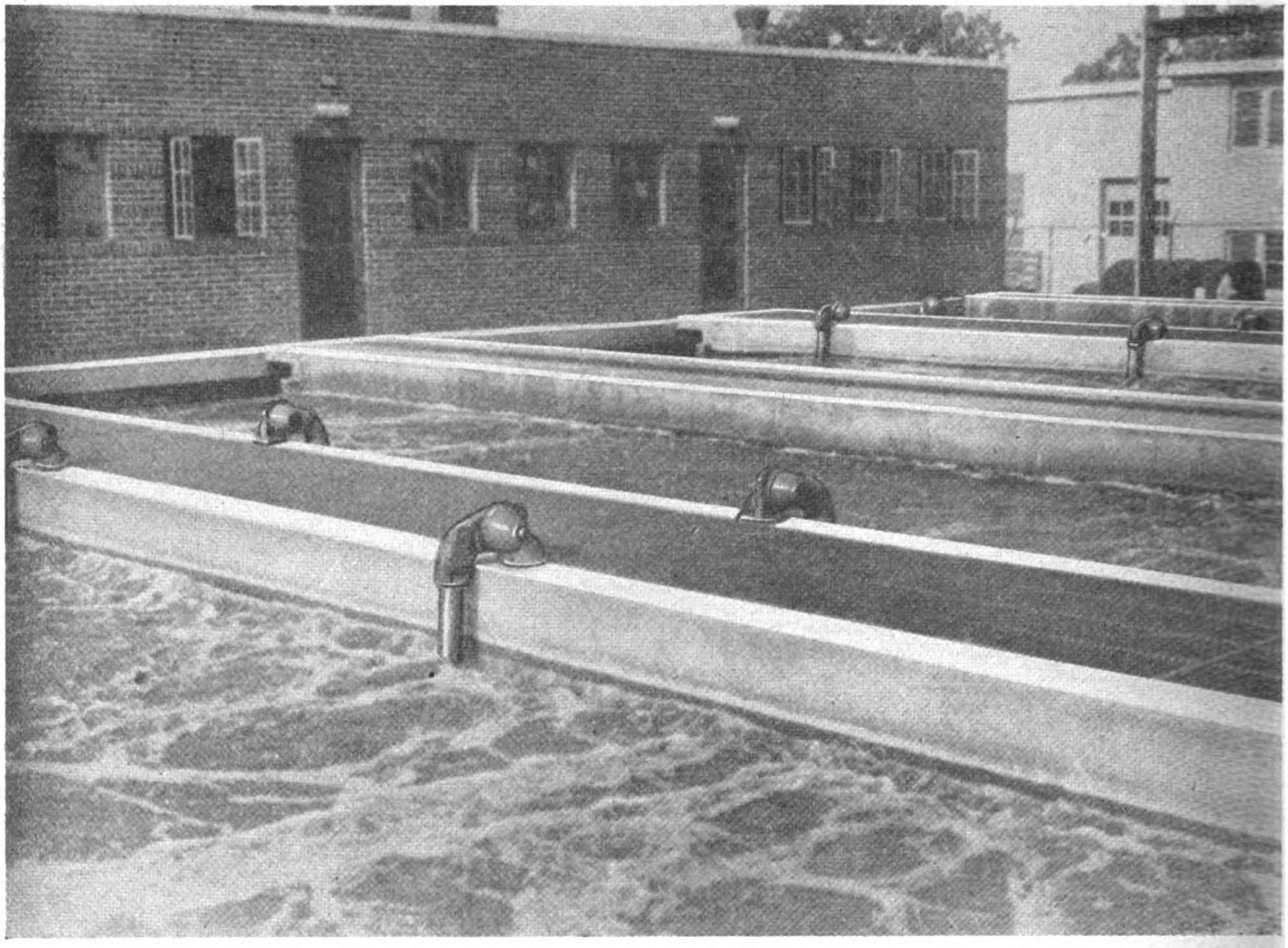


FIGURE 106. *Spiral-flow aeration.*

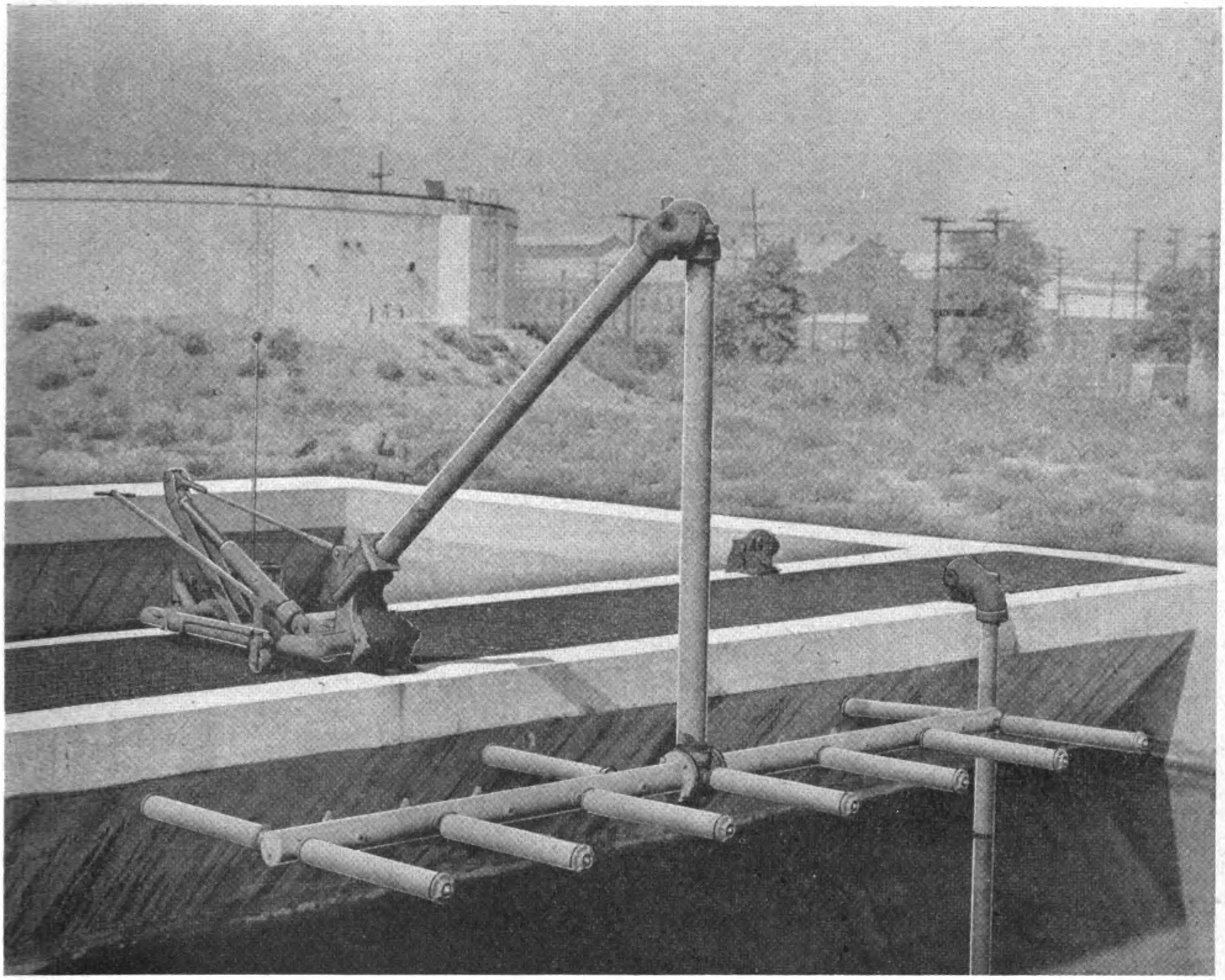


FIGURE 107. *Swing type diffuser in raised position for servicing.*

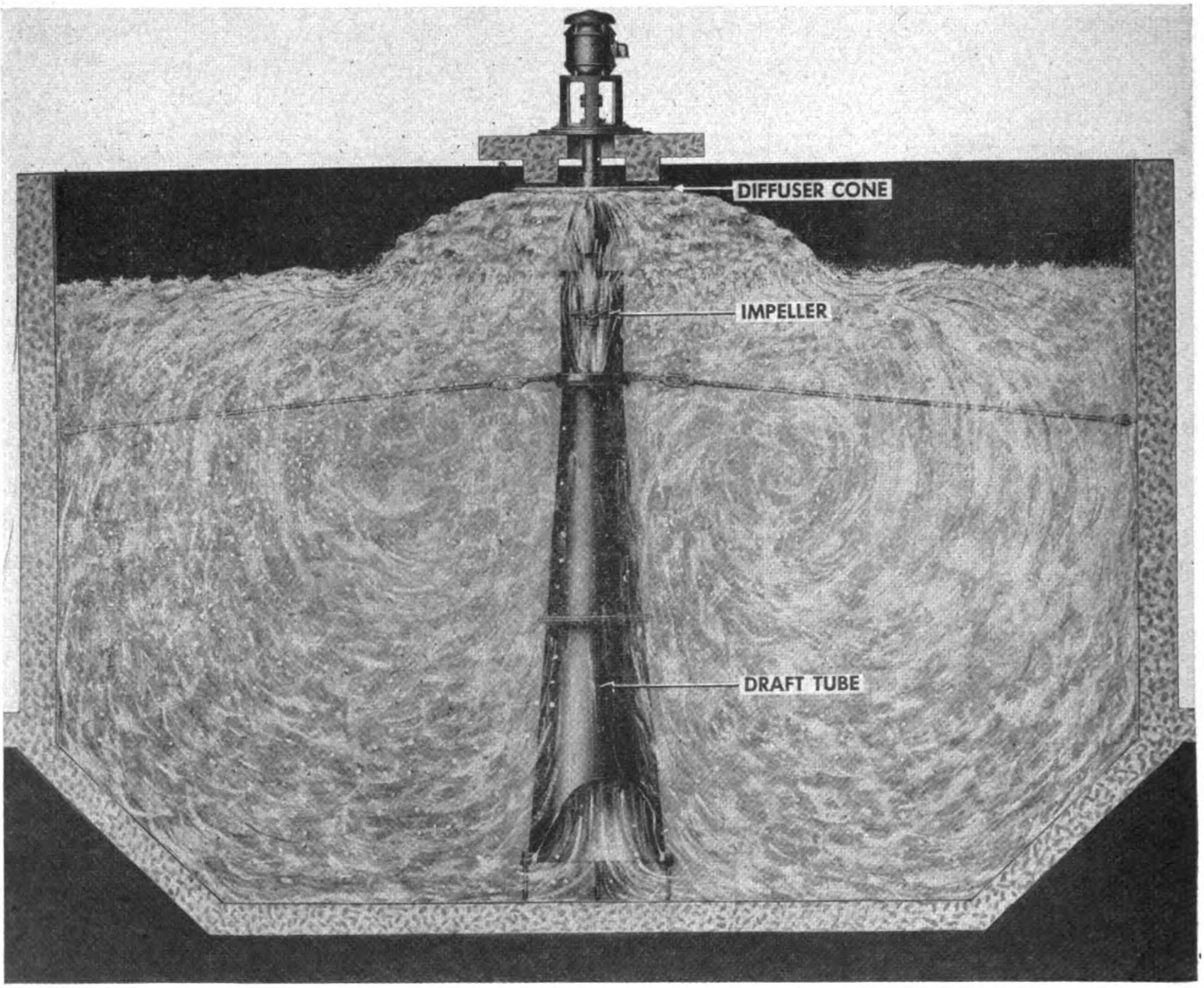


FIGURE 108. *Updraft mechanical aerator.*

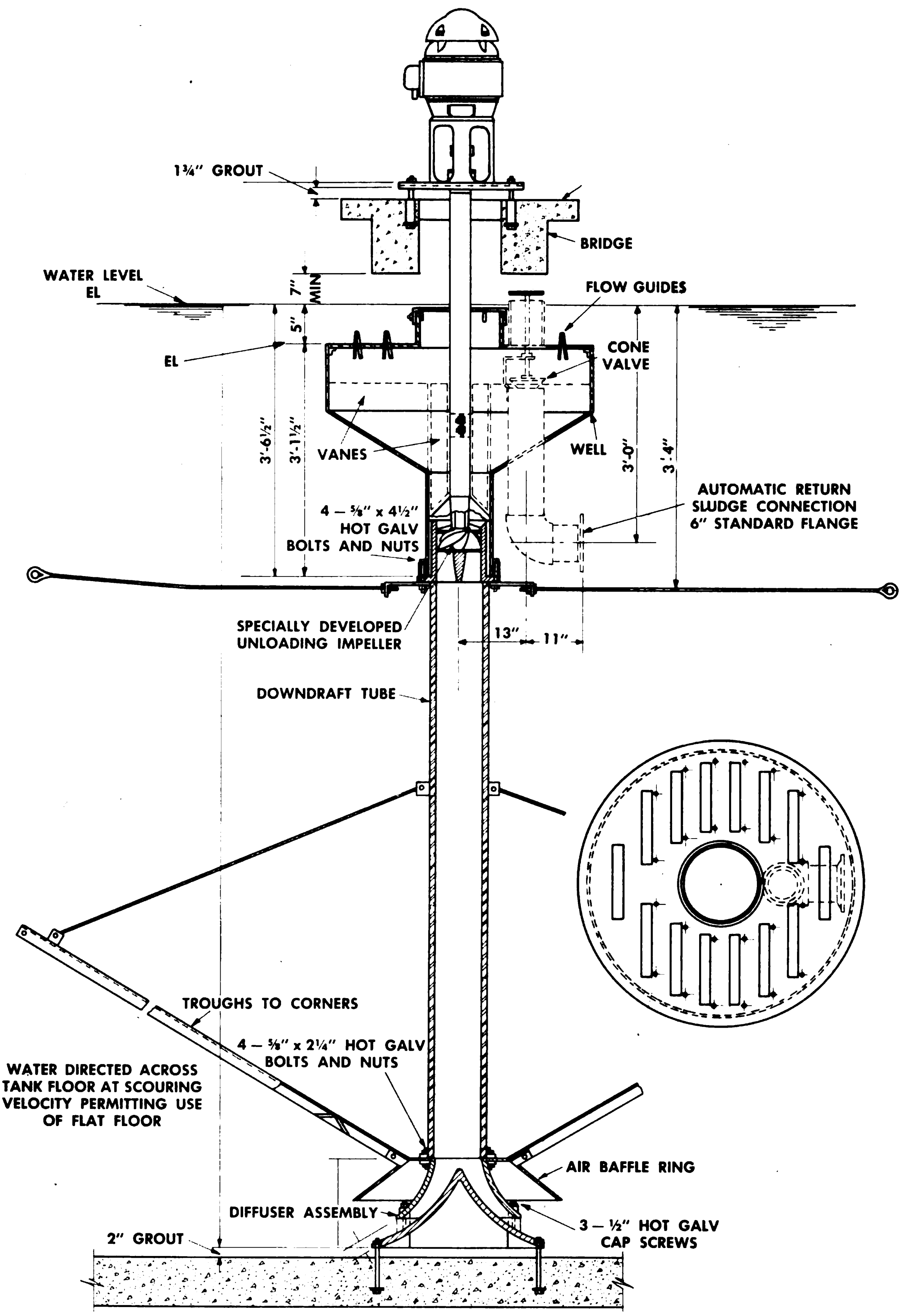


FIGURE 109. *Downdraft mechanical aerator.*

113. Aeration Tanks and Equipment

Rectangular tanks are usually adapted to diffused-air aeration, while mechanical aerators are installed in square tanks arranged in series. Tanks at Army plants are designed for detention periods of 8 hours for diffused-air and 12 hours for mechanical aeration, based on average flow plus recirculation. Sludge is returned from secondary-settling units by gravity or by pumps. Figure 109 shows the automatic-return line for a mechanical aerator. Sludge return is controlled by weir boxes or orifices; on gravity lines, adjustable sleeves on pipes to the settling-tank hopper control the return. TM 5–666 gives maintenance instructions for diffusers, compressors, and mechanical aerators.

114. Plant Operation

a. FACTORS INVOLVED. Extent of purification depends upon proper control and adjustment of the biological process. Plant operators must determine the best operating range of all factors involved by systematic trial and establish procedures by study and observation to meet variable conditions. These factors include the following:

(1) Concentration of solids in mixed liquor.
(2) Settling rate of mixed-liquor solids.
(3) Volume of sludge return.
(4) Concentration of solids in return sludge.
(5) Quantity of air required for various loadings.

b. QUALITY OF ACTIVATED SLUDGE. (1) *Characteristics.* High quality activated sludge settles rapidly, leaving a clear, odorless, stable liquid above; it is usually golden brown and has a slight musty odor. The floc usually appears to be granular with sharply defined edges. Settling characteristics may be determined by allowing 1 liter of mixed liquor to settle for 1 hour in a graduate and periodically noting the volume of settled sludge. Settling to a volume of 20 to 30 percent in 10 minutes indicates good sludge. Figure 110 shows good and poor settling qualities for activated sludge.

(2) *Density.* Dense sludge is desirable. Density expressed as sludge index is computed by dividing percent of volume after 30 minutes settling by percent mixed-liquor suspended solids. *Example:* If sludge settles to 20 percent volume in 30 minutes with aeration solids at 1,000 ppm (0.1 percent), the sludge index is $\frac{20\%}{0.1\%}$ or 200. An index less than 100 is usually expected in diffused-air plants; with mechanical aeration, it usually is 200 to 300. A higher index than normal indicates bulking. (See par. 117.)

c. QUANTITY OF ACTIVATED SLUDGE. The amount of sludge, measured by the suspended solids in the mixed liquor, must be great enough to produce the desired purification in the available aeration time and low enough to give economical air utilization. Mixed-liquor solids concentration, sewage strength, aeration time, and quantity of air are all interrelated.

(1) *Proper concentration.* The concentration of mixed-liquor solids for best operation under all conditions must be determined for each plant by trial. Aeration-solids concentrations of 1,200 to 3,000 ppm in diffused-air plants and 500 to 1,200 ppm in mechanical plants are usual, but they may be varied to suit seasonal or plant-load conditions.

(2) *Excessive concentration.* Maximum solids concentration to be carried is limited by air supply and raw-sewage load. If solids build up indefinitely, the air and food requirements ultimately exceed the available supply and upsets occur. After the desirable solids concentration in mixed liquor is determined, it is maintained by wasting part of the return sludge. Where shock loads are imposed by sewage varying widely in strength, the solids content of mixed liquor must be enough to absorb the shock. For economy, excessively high solids concentration cannot be carried merely because the available blower capacity permits it. Because of wide variations and high peaks in sewage strength at Army posts, a higher concentration of mixed-liquor solids is necessary than in municipal plants.

(3) *Tests.* Control tests for mixed-liquor and return-sludge suspend solids and settled volume are made daily or preferably once each shift.

d. QUANTITY OF AIR. Although most of the oxygen dissolved in the mixing liquor during aeration is used by the activated sludge, it is only 2 to 5 percent of the oxygen supplied to the tanks. Air requirements are governed by BOD loading, quality of sludge, and solids concentration of mixed liquor.

(1) *Control.* In diffused-air plants, air application is usually controlled by blower combinations or variable output blowers. Air supply in mechanical plants is governed by the number of units in service and automatic time switches on each aerator.

(2) *Tests.* Make dissolved-oxygen determinations daily or preferably each shift, on examples of the mixed liquor collected at the inlet end, middle, and outlet end of the aerators. Inhibitor (par. 166)

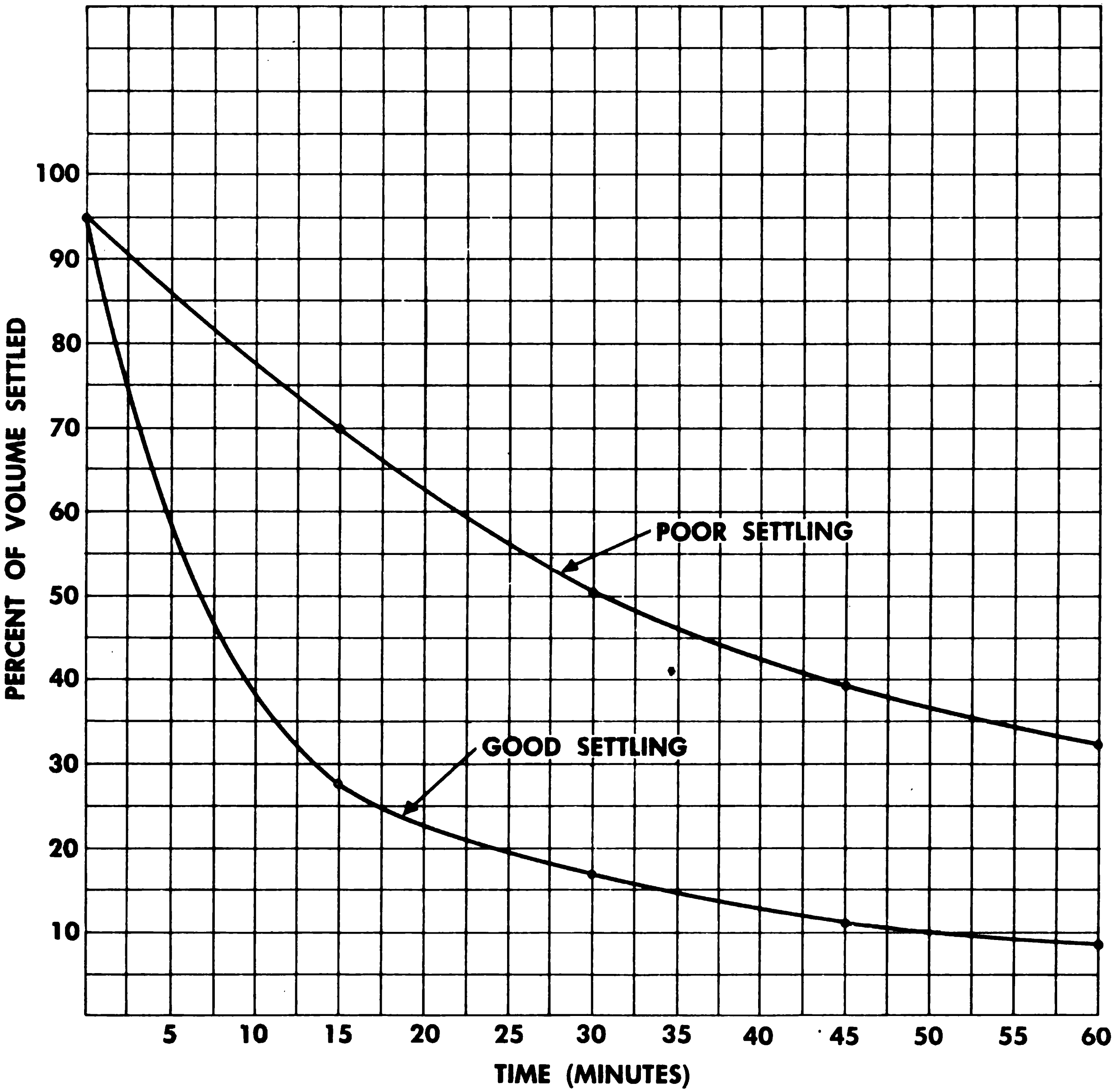


FIGURE 110. *Curves showing condition of activated sludge.*

is used in collecting dissolved oxygen samples to arrest bacterial action and oxygen utilization; otherwise low test results are obtained. These tests indicate whether or not air supply is satisfactory. If 1 ppm of dissolved oxygen is present at the inlet and progressively builds up to 4 or 5 ppm at the end, air supply is adequate.

(3) *Excessive application.* Excessive air application is wasteful and may cause the flocculent sludge to be finely dispersed and difficult to settle. Much of it passes over the settling-tank outlet weirs.

e. AERATION PERIOD. Approximately 80 to 85 percent of sewage purification occurs during the first hour of aeration. During the rest of the period, sludge is regenerated, organic matter stabilized, and sludge conditioned for further activity. The sludge's capacity for taking in organic matter is limited and regeneration is necessary before an additional load is applied. Activated sludge requires oxygen at a definite, measurable rate. It absorbs oxygen from the water as rapidly with only a few ppm in solution as when the water is almost saturated.

(1) *Oxygen utilization.* Oxygen utilization, initially rapid, follows a fairly well-defined, tapering curve to a lower, more even rate as treatment progresses. Time required for purification is in inverse proportion to the amount of sludge. Doubling the quantity of suspended solids in the sewage sludge mixture halves the time for complete oxidation if hydraulic and mechanical conditions permit settling out the increased sludge, and enough dissolved oxygen is available.

(2) *Measuring utilization.* Oxygen utilization over a short period of time can be measured by procedure given in paragraph 167. It is expressed as rate of oxygen utilization in ppm per hour. The curve in figure 111 shows what happens to any unit volume of mixed liquor passing through an activated-sludge plant. Before treatment starts, return sludge whose liquid portion has a low oxygen demand and raw sewage usually having a low immediate oxygen demand and a high BOD are present. At zero time period of treatment on the curve, return sludge and raw sewage are being mixed together and the aeration process started. At this point the rate of oxygen utilization is maximum and remains constant for some time. The length of this period of constant rate of absorption varies directly with strength of sewage and inversely with amount of sludge, other factors remaining constant. After holding for some time, oxygen utilization decreases abruptly a first to an almost constant rate as aeration proceeds for several hours.

(3) *Use of oxygen curve.* Characteristic curves show the maximum rate of oxygen utilization to be definitely related to the rate of utilization at completion of the process. This ratio, at least 3:1 and usually 4:1, guides proper adjustment of air distribution to meet oxygen demand. Tapered or step aeration to vary air distribution saves total air used by placing proper amounts where they are needed.

(4) *Adjusting aeration tanks.* Aeration periods of 8 hours for diffused aeration and 12 hours for mechanical aeration are desirable. Adjustment to conform to factors discussed above improve plant operation. In mechanical aeration tanks at Army posts, maintaining dissolved oxygen in first stage of aeration is often difficult. Figure 112 shows small diffuser units installed to boost the oxygen supply.

115. Return Activated Sludge

a. Rate of return. Volume of activated sludge returned from final-settling tanks to aeration tanks normally ranges from 20 to 40 percent of the raw sewage flow. A high rate of return reduces aerator detention but keeps sludge fresh and may return needed dissolved oxygen to the aerator inlet. a low rate of return increases aerator detention

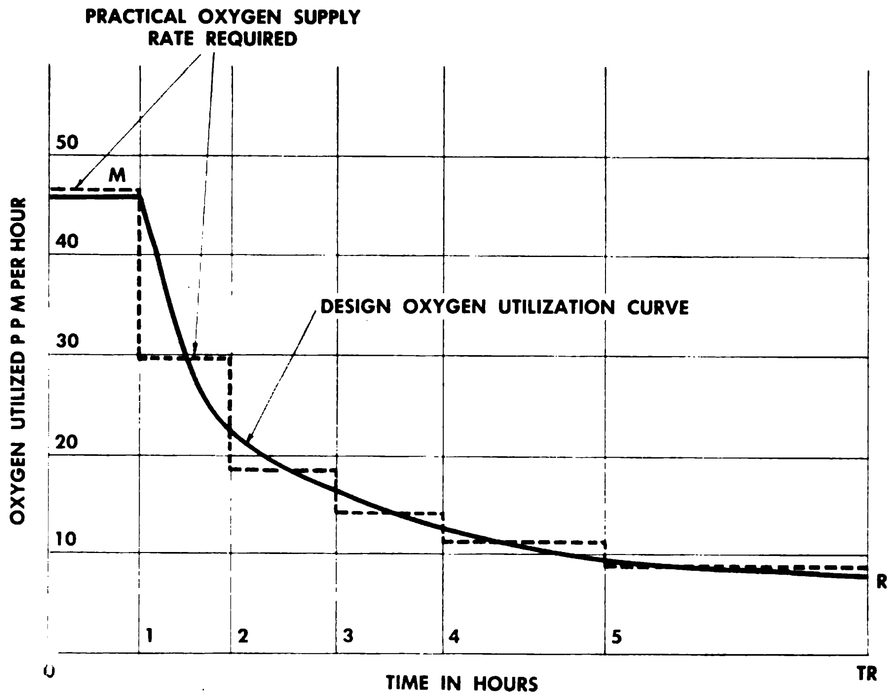


Figure 111. *Oxygen-utilization curve.*

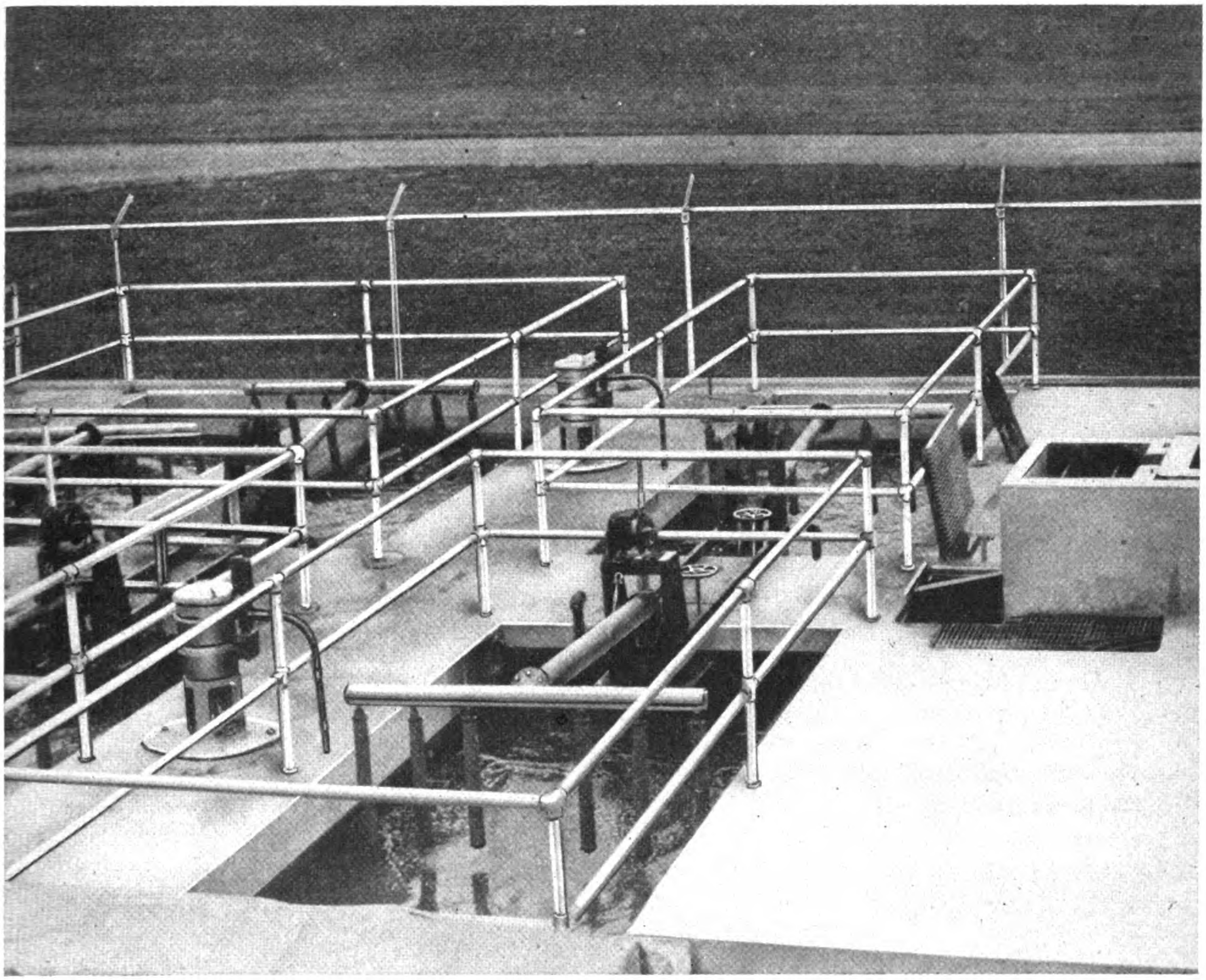


FIGURE 112. *Auxiliary diffused-air units in mechanical aeration tanks.*

time; it is feasible when the sludge has a low rate of oxygen utilization and does not readily become septic. A high return-sludge concentration is obtained with low return rate.

b. RATE OF WASTE. A division is usually provided to split the flow of returned sludge from the final-settling tank either to waste or to aeration-tank influent. Suspended-solids concentration in the aeration tank and return sludge determine when and how much sludge is diverted to waste. Routine schedules must be developed for wasting sludge in small amounts daily, holding solids in the aeration tank nearly constant. Sludge is wasted slowly and uniformly, generally during periods of low flow.

116. Final-setting Tank

Because settled sludge must be maintained fresh for return to the aeration tanks, the sludge blanket in the settling tank is kept below 2 feet. Mechanical sludge-collection equipment must be operated continuously. Hoppers are squeegeed often to free them of septic sludge. Short-circuiting and eddy currents are corrected; walls, weirs, and channels are hosed down daily. Rising sludge which is black on the underside indicates that sludge is sticking on the walls or floors; these areas must be kept free of accumulated sludge.

117. Operating Difficulties

a. OIL AND GREASE. Oils and grease from mess halls or laundry wastes harm bacteria growth in the aeration tanks. The sources of grease and oil are eliminated by proper cleaning of grease traps and oil interceptors. Primary-settling tanks are kept skimmed off.

b. Bulking sludge. (1) A sudden loss of sludge density shown by poor settling, passage of floc through the final-settling tanks, and increased sludge index is known as bulking. It occurs in two forms:

(*a*) A large diffused floc resulting from loss of biological balance.

(*b*) A light floc containing *Sphaerotilus*, a microscopic threadlike fungus growth. (See fig. 113.)

(2) Bulking may be caused by the following:

(*a*) Too high or too low aeration-tank solids concentrations.

(*b*) Inadequate air supply.

(*c*) Inadequate aeration period.

(*d*) Sudden heavy loads on the system such as a heavy dose of strong digester supernatant or an overload of stale or septic sewage solids flushed to the plant by rains after a long dry period.

(*e*) Sewage abnormally high in organic solids, especially sugars and starch.

(*f*) Fungus accumulations from the sanitary sewer system.

(3) When bulking results in septic aeration units, wasting the sludge and redeveloping a healthy floc may be necessary. In the early stage of bulking, reconditioning is aided by increasing sludge return and amount of air.

(4) Fungus growths usually can be controlled by the following:

(*a*) Applying chlorine to the return sludge in doses of 1.0 to 8.0 ppm of sludge-return flow. (See par. 143.)

(*b*) Adding ferric chloride to the mixed liquor.

(*c*) Adding copper ammonium sulphate to return sludge.

(5) Rising sludge in final-settling tanks is usually caused by an excessive retention period forming gases which lift the sludge in chunks. Increasing the sludge-return rate to lower the sludge blanket corrects the trouble. This condition also may be caused by nitrification brought on by excessive aeration.

c. Effect of digester supernatant. Digester-supernatant disposal in the activated-sludge plant is troublesome, especially when the digester is not functioning properly. Supernatant is usually returned to the plant influent where it passes through the entire plant process. Being well seeded with the organisms of anaerobic digestion, it tends to increase the septic action in the settling units. If discharged intermittently during sludge pumping, it throws a heavy load on the secondary process. If the mixed liquor is not in condition to receive this load, the sludge soon becomes gray and septic.

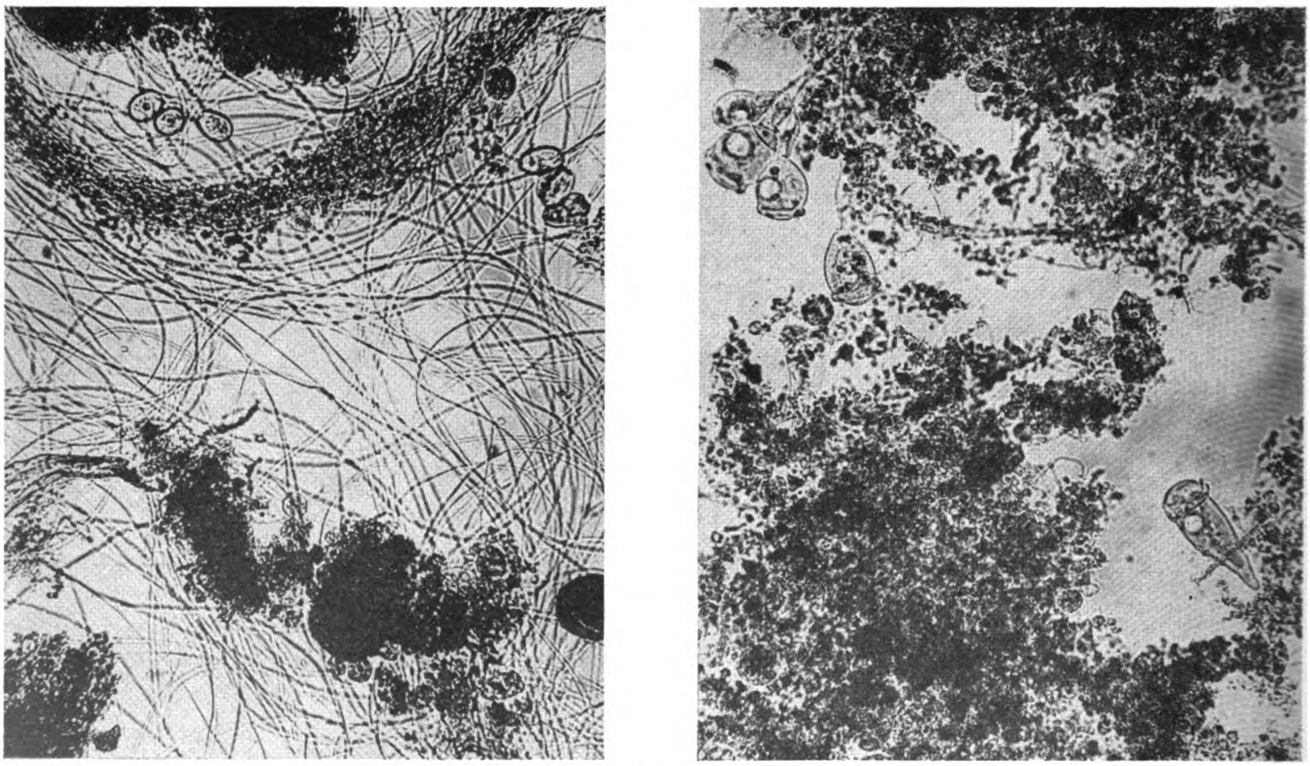


Figure 113. *Photomicrographs of activated sludge. Bulking sludge containing SPHAEROTILUS on left, normal sludge on right.*

(1) Supernatant is returned as uniformly as possible.

(2) Returning it directly to the aerator often eliminates the difficulties.

(3) Returning it to the aerator during low loadings is sometimes successful.

(4) If the supernatant is returned intermittently, the solids in the mixed liquor must be in condition to receive it (higher in concentration). The DO must be carefully watched and increased during the period if necessary.

118. Records and Reports

The following data are reported on the monthly operating logs:

a. BOD, suspended solids, settleable solids, and relative stability of final-tank effluent.

b. DO of mixed liquor at inlet and outlet ends of aeration tanks.

c. DO of final-settling tank effluent.

d. Volume of return sludge.

e. Volume of waste activated sludge.

f. Suspended solids in mixed liquor and return sludge.

g. Percent settled-solids volume in mixed liquor and return sludge (30 min.).

h. Sludge index.

i. Volume of air (in 1,000 cubic feet) or hours of operation of mechanical aerators.

j. Remarks of unusual conditions such as bulking, its cause and control, peak loads, etc.

Section XII. CONTACT AERATION

119. Type of Construction

The contact-aeration process at Army installations normally uses contact aerators in two stages. Figure 114 shows the usual flow diagram. Each aerator is divided by an overflow dividing wall into two sections operated in series. Figure 115 shows the component parts of a single stage. Each plant has air blowers and accessories for compressing air and blowing it through the perforated-pipe system. Figure 116 shows the pipe grid mounted under the contact plates. Sludge-digestion facilities and settling-tank design are similar to other types of plants. Sludge from the hoppers in each tank unit discharges under hydrostatic head through plug valves to adjacent sight wells then to a raw sewage well, sludge sight well, or a sludge pump. In some installations, the sludge-withdrawal line from the primary-settling tank is directly connected to a sludge pump; in others, the sludge is drawn under hydrostatic head to a sludge well from which the pump can take suction. Low-head pumps and pipe lines for recirculating second-stage aerator effluent to first-stage aerator influent are often added to improve plant effluent and eliminate odors. Figures 117 and 118 show typical contact-aeration plants.

120. Functioning

Settled sewage passes between stationary contact media of cement-asbestos plates on which a biological film develops. An aerobic condition is maintained by blowing air through the contact section

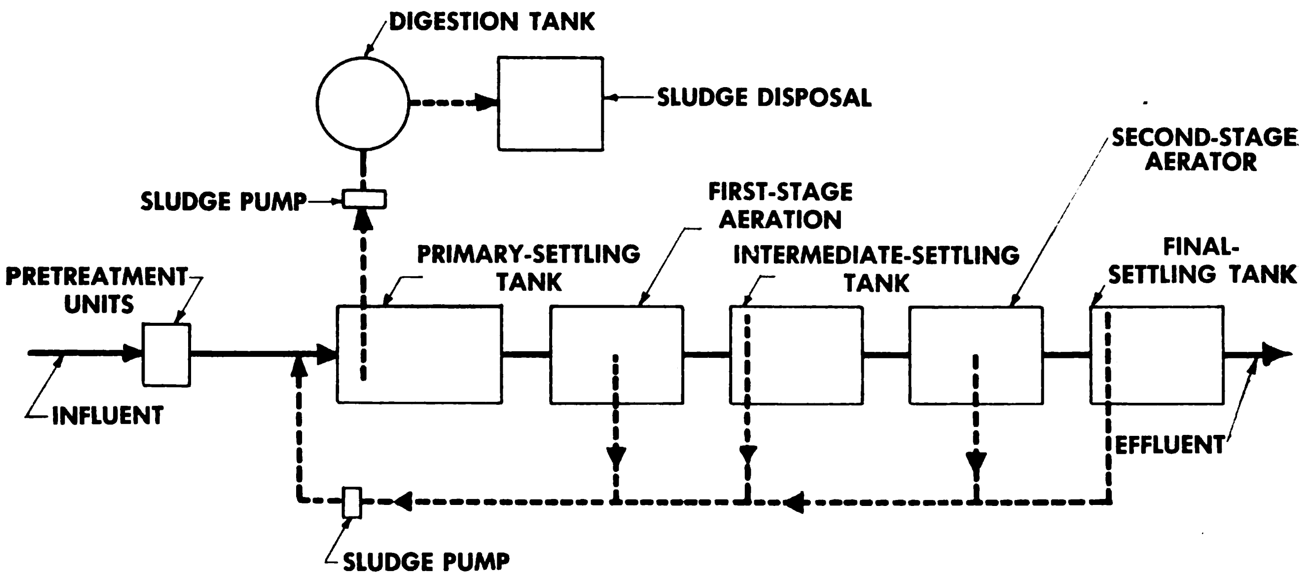


FIGURE 114. *Flow diagram of a contact-aeration plant.*

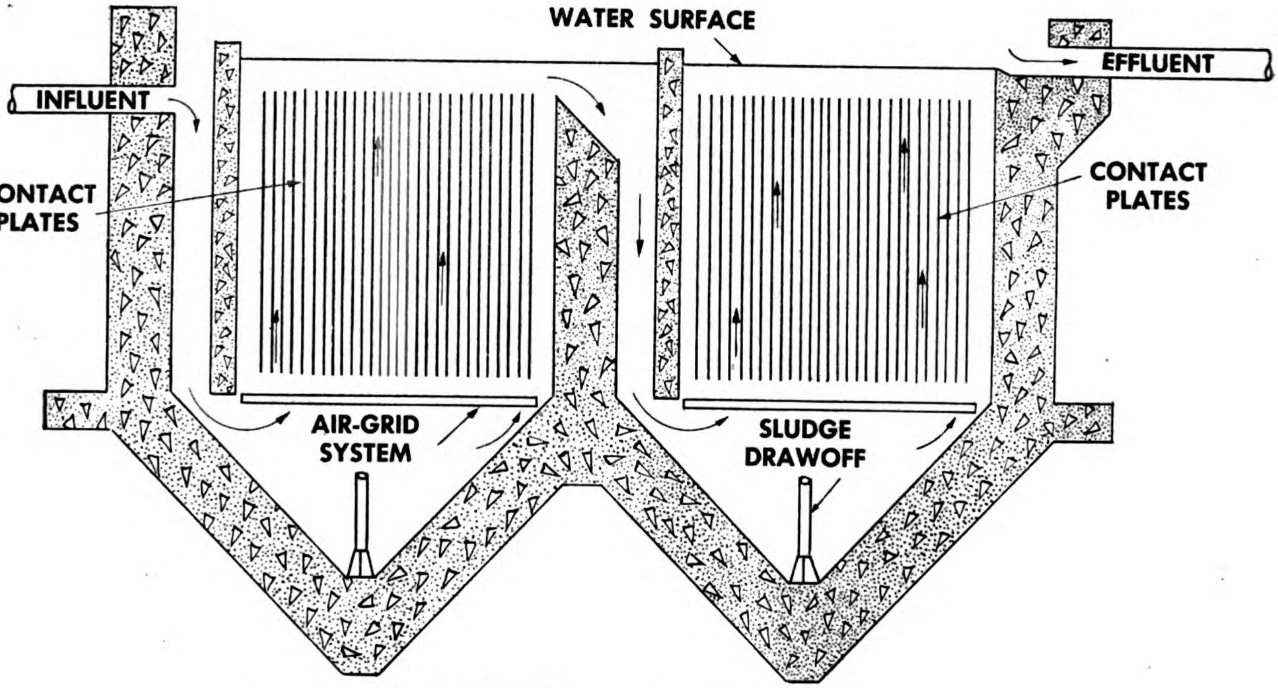


FIGURE 115. *Single-stage section of contact aerator.*

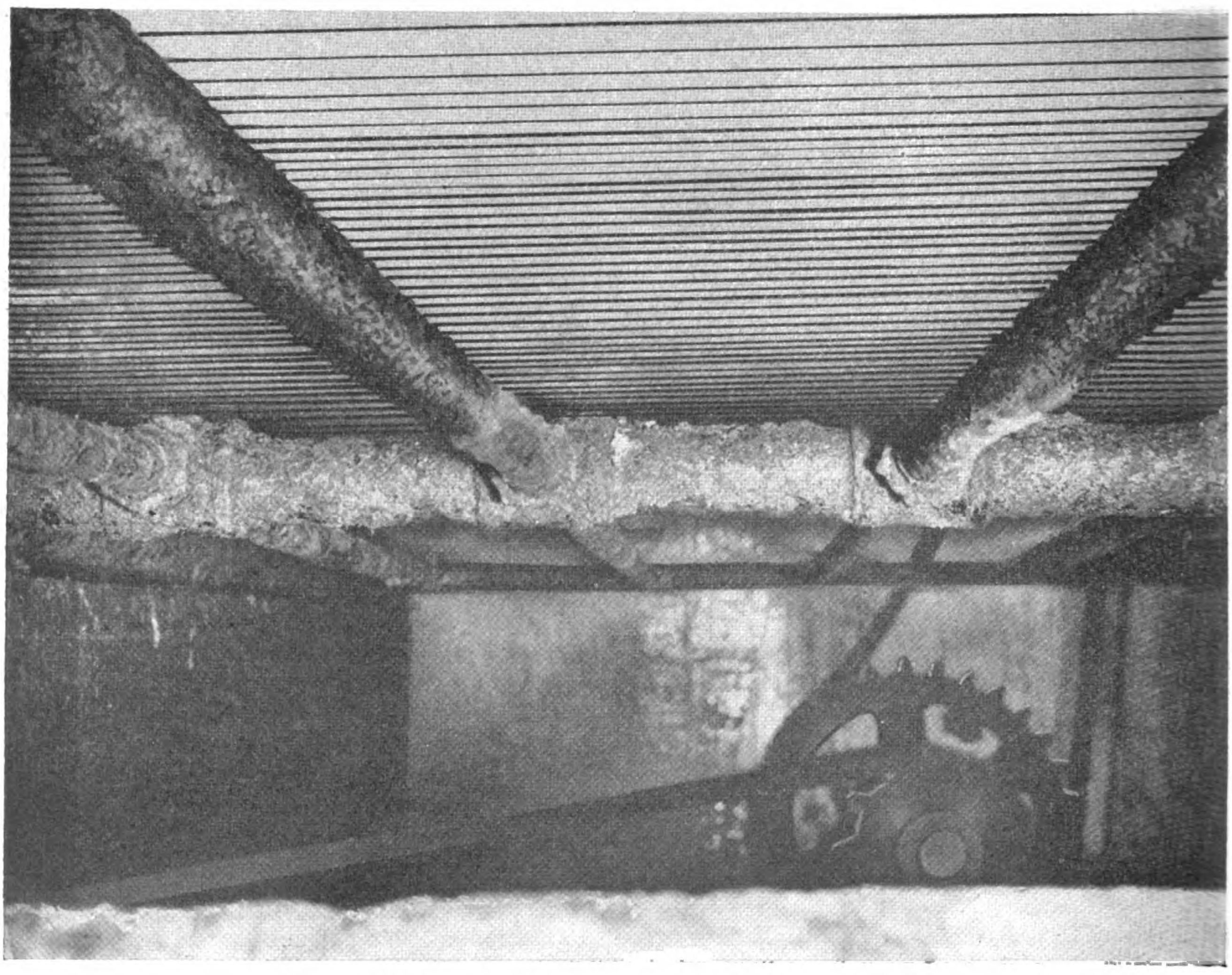


FIGURE 116. *Perforated-pipe air-distribution grid under contact plates.*

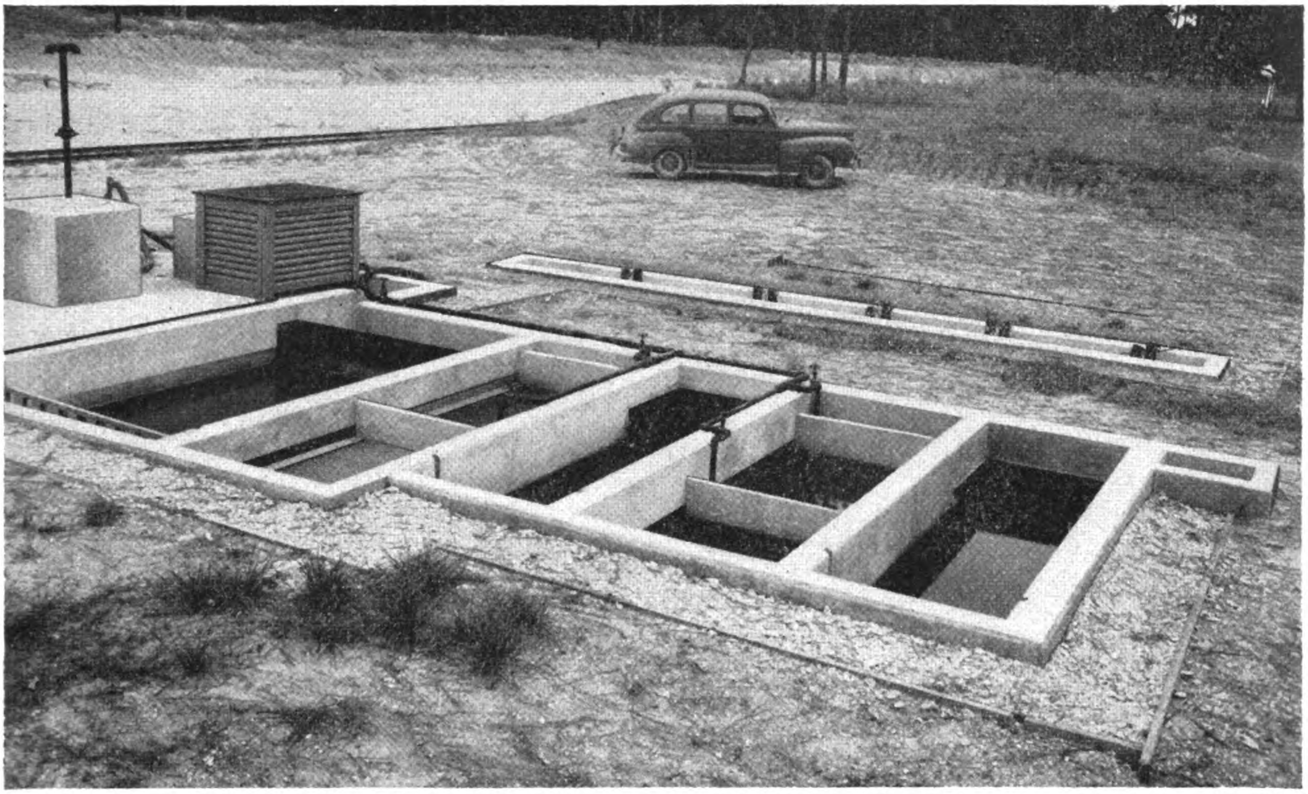


FIGURE 117. *Small contact-aeration tank.*

from perforated pipe mounted below plates. Submerged aerobic biological life treat and stabilize sewage. Since the treatment is quite sensitive to loading changes and operating conditions, proper operation of settling tanks and digesters is essential. Treatment action is comparable to the trickling filter, where biological life forms on the stones instead of plates. Like the activated-sludge process, biological life is also suspended in the liquor which is kept aerobic by air blown in or mechanically entrained at the tank surface. Organisms in a properly operated contact aerator are quite similar to those in the trickling-filter film and identical with activated sludge. Improperly functioning units contain many organisms commonly found in digesters or other anaerobic processes. Many more sulfur bacteria are present in the contact aerator than in most other secondary-treatment units. When the dissolved oxygen disappears and an anaerobic condition develops, aerators produce considerable hydrogen sulfide.

121. Operation

Good operation is achieved by maintaining an aerobic condition in all flow units following the primary-settling tank. Air distribution must be efficient, and sludge in units following the primary settling tank must not become septic.

a. RECIRCULATION. Contact-aeration plants usually function satisfactorily without recirculation at 60 percent or less of the Army design loading although hydrogen sulfide odors occasionally persist below this loading. Recirculation from the effluent channel of the second-stage aerator to the inlet end of the first-stage aerator eliminates odors and produces a high degree of treatment at full loading. The second-stage aerator effluent contains the highest DO concentration and many aerobic organisms. When this liquid is returned to the first stage, DO to meet the initial high oxygen demand is provided and the returned organisms seed the film growth on the plates. A low-head pump or air lift and necessary piping should be installed for recirculation where needed. Figure 119 shows recirculation discharge at a large plant. Enough recirculation must be provided for a 45-minute detention period in the intermediate-settling tank at average daily rate of flow. This may be modified to suit local conditions. A minimum DO of 1 ppm in first half of the first-stage aeration must be provided.

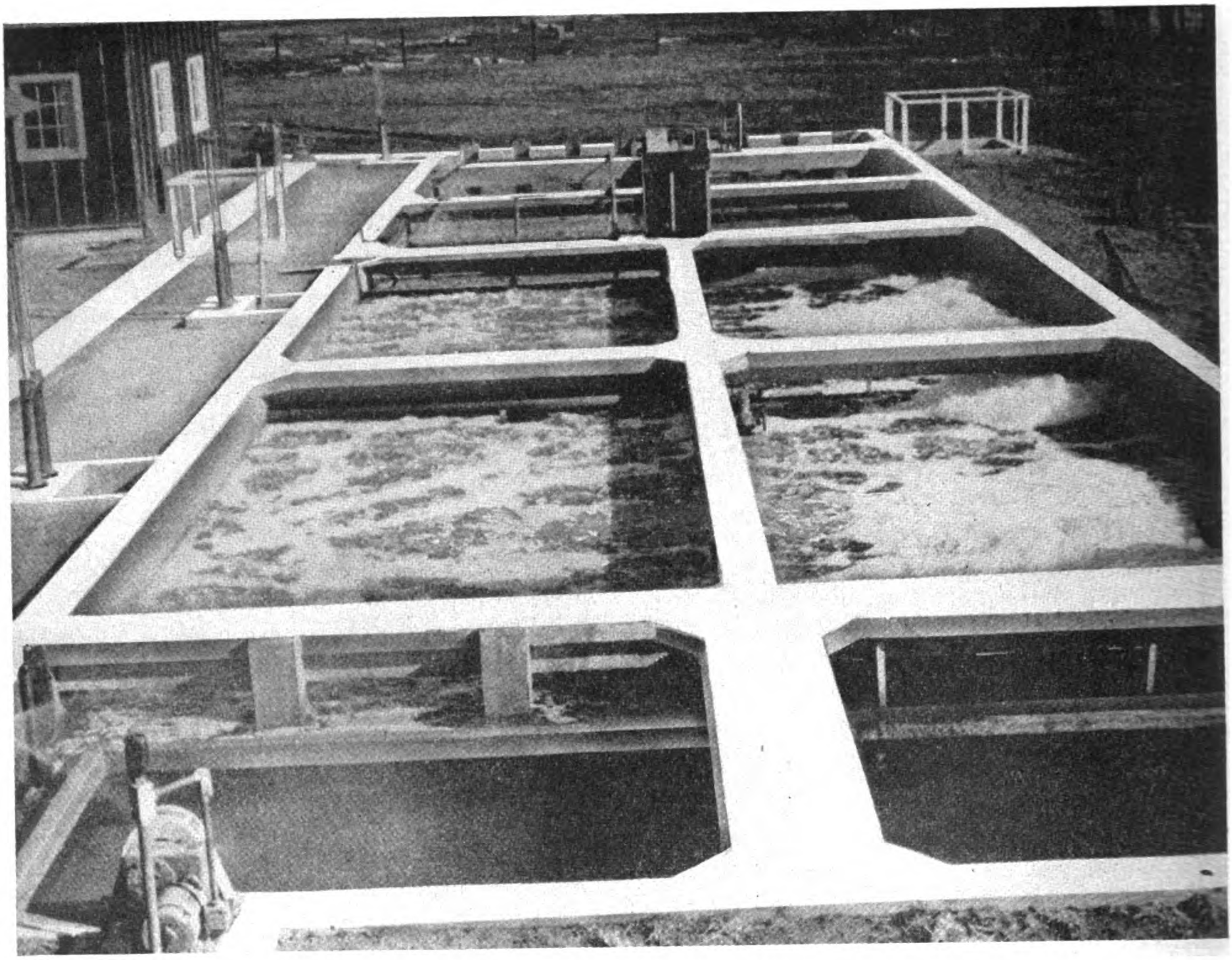


FIGURE 118. *Contact-aeration plant.*

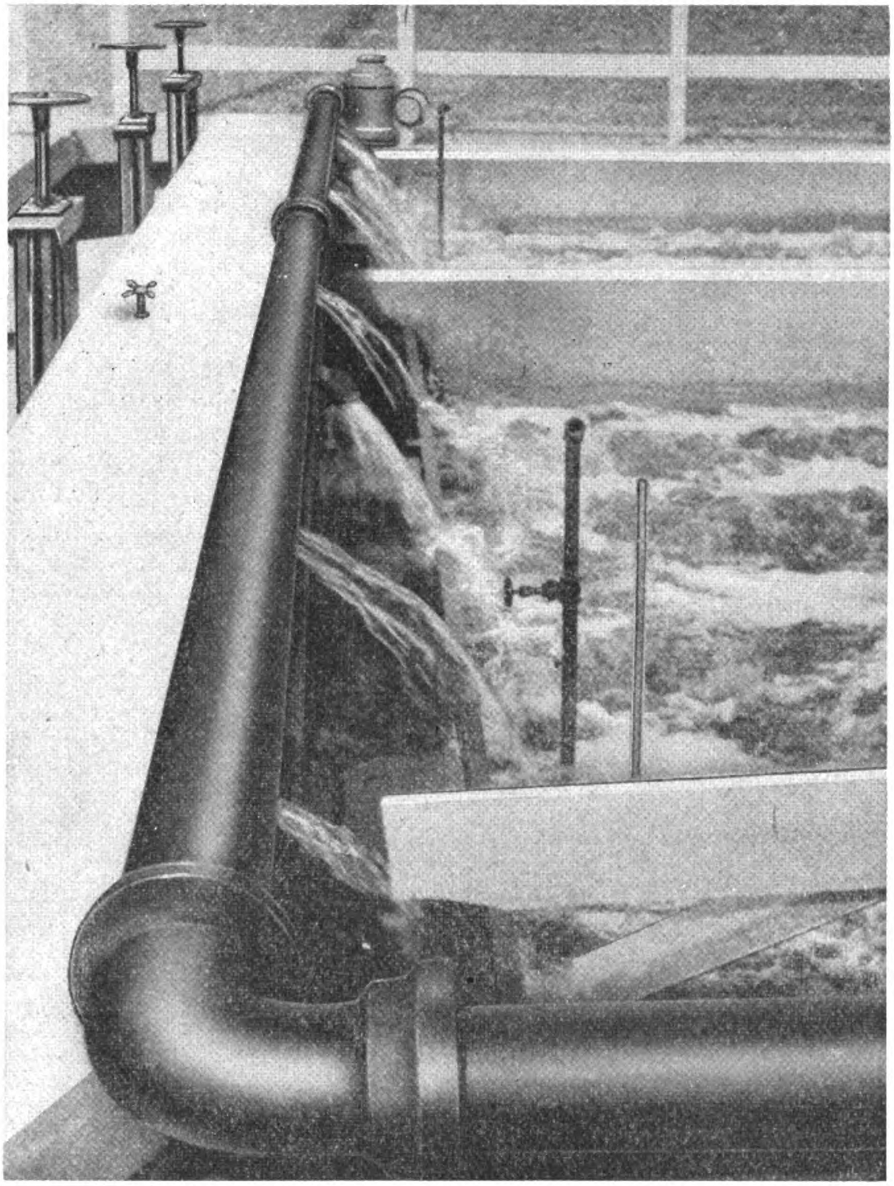


FIGURE 119. *Recirculation of second-stage aerator effluent.*

b. PREAERATION. Operating efficiency is sometimes improved by preaeration of raw sewage through a small air line placed on the floor of the influent or grit channel. Small chambers with submerged perforated pipe or diffusers for air distribution, originally installed for grease flotation, have much greater value as preaeration units. Aeration periods of 5 to 20 minutes considerably improve reaction of sewage to further treatment.

c. CONTACT AERATORS. The dissolved-oxygen determination is the principal control test in operating contact aerators. Frequent determinations plus observations of tank liquor and plate growth permit the operator to achieve maximum efficiency.

(1) *Starting operation.* Primary effluent is applied to contact aerators gradually during initial plant operation or when aerators are returned to service after the plates have lost their growth. Aerators may be started with a rate of flow not over 25 percent of normal. When a DO of 1 ppm is obtained in the first stage, the rate of flow through the aerators may be raised by small amounts, still maintaining a DO concentration of 1.0 ppm in the primary-aerator effluent. Recirculation during the starting period should be at the maximum rate and continued until the total sewage flow is passing through the entire plant. If treating entire sewage flow in this manner is difficult, technical assistance from the service command engineer should be obtained.

(2) *Air supply.* The number of blowers operated during any period of the day is governed by average rate of flow during that period as well as by DO concentration in effluents of the primary and secondary aerators. A minimum DO concentration of 1.0 ppm is maintained in the primary-aerator effluent and 3.0 ppm in the secondary-aerator effluent. Air valves are regulated to apply approximately two-thirds of the air to the primary aerator. During low-flow periods, one or more blowers are cut off if proper DO concentrations can be maintained. TM 5–666 covers preventive maintenance of blower equipment.

(3) *Sludge withdrawal.* Sludge is withdrawn from contact aerators about once every 4 hours and returned to raw-sewage flow. The sludge must not become septic and should not be stored a long time between withdrawal and return.

(4) *Air distribution.* Uniform air distribution is necessary for efficient use of air and preventing anaerobic growths between the plates at dead spots. Observations for dead spots and air-pressure readings are recorded daily. Procedure for the blowing of the air grids daily to keep perforations open is given in TM 5–666. At plants with overhead air distribution (fig. 120), drop pipes are disconnected at the unions for removal and cleaning of perforated pipe. Where maintenance cost of the perforated-pipe air-distribution system is excessive or complete replacement is required, consideration may be given to installing porous-tube diffusers. (See fig. 121.) Locating all diffusers at the center line of the tank to produce a double-spiral motion of liquid is more satisfactory than the arrangement shown in figure 121. The hopper bottom has been filled in. Circulation under the diffusers prevents accumulation of solids.

FIGURE 120. *Overhead air distribution in first-stage aerator. Drop pipes can be disconnected at unions for removal and cleaning of perforated pipe mounted at bottom.*

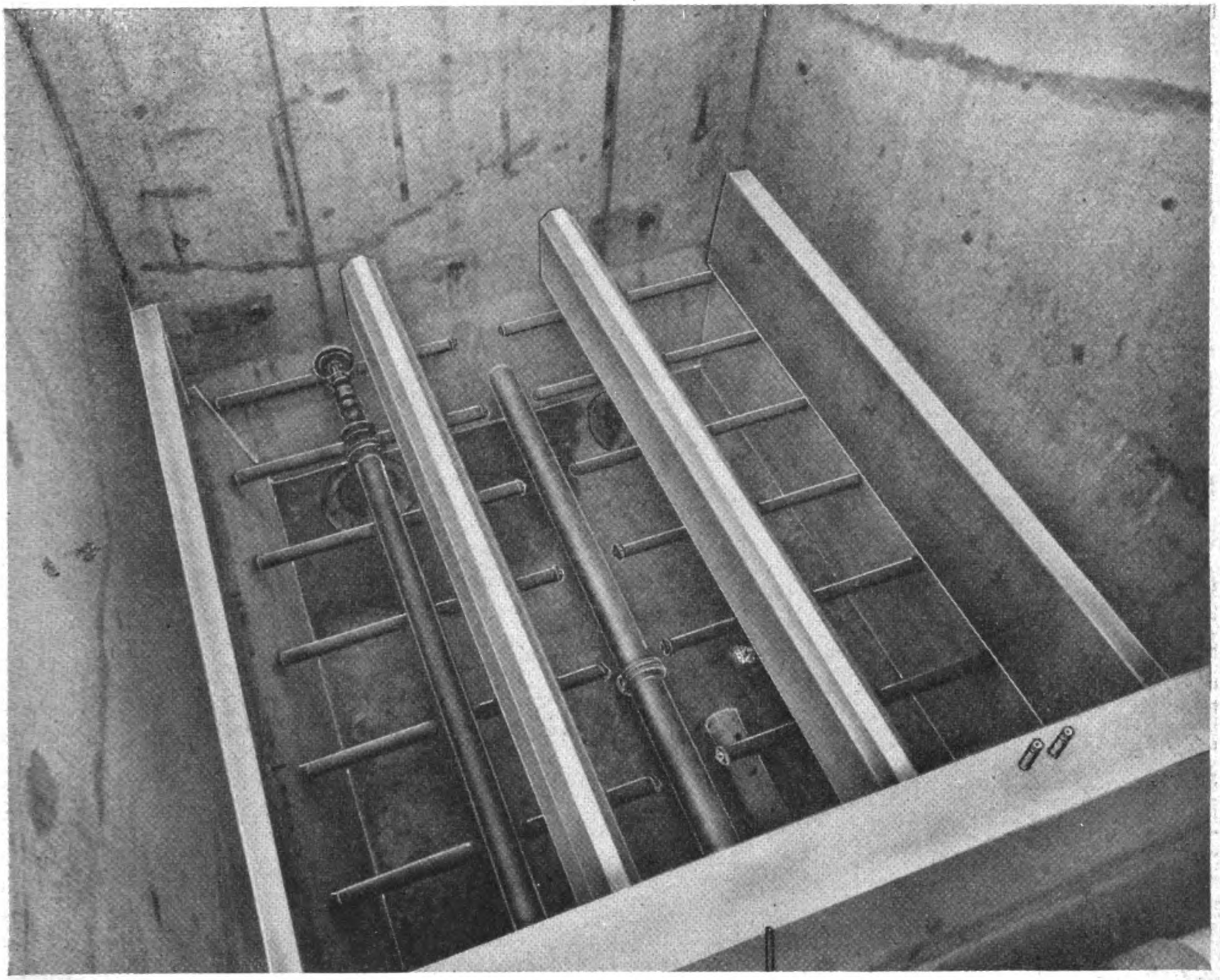


FIGURE 121. *Porous diffuser tubes.*

(5) *Cement-asbestos plates.* Observation plates, cement-asbestos plates about 6 inches wide and 4 feed long with a batten on one side, are placed in each of the aerator sections between the contact plates. They are observed at least once each week and growth characteristics are recorded. The color of the growth indicates its oxidizing power, brown, thin film being most desirable with a grayish, thin film next. Black film or any underlying black portion indicates reducing action and is not desirable. Figure 122 shows thin film on a contact plate. A hydrogen sulfide odor from an aerator section indicates absence of aerobic condition in part or all of the section. Heavy plate growth may be knocked off with high-pressure water or compressed air. Figure 123 shows use of air for cleaning plates. If the growth's color near the plate is brown or gray or if other signs of good aerobic condition are present in the aerators, the growth need not be knocked off. Instructions in TM 5–666 for preventive maintenance of contact plates must be followed.

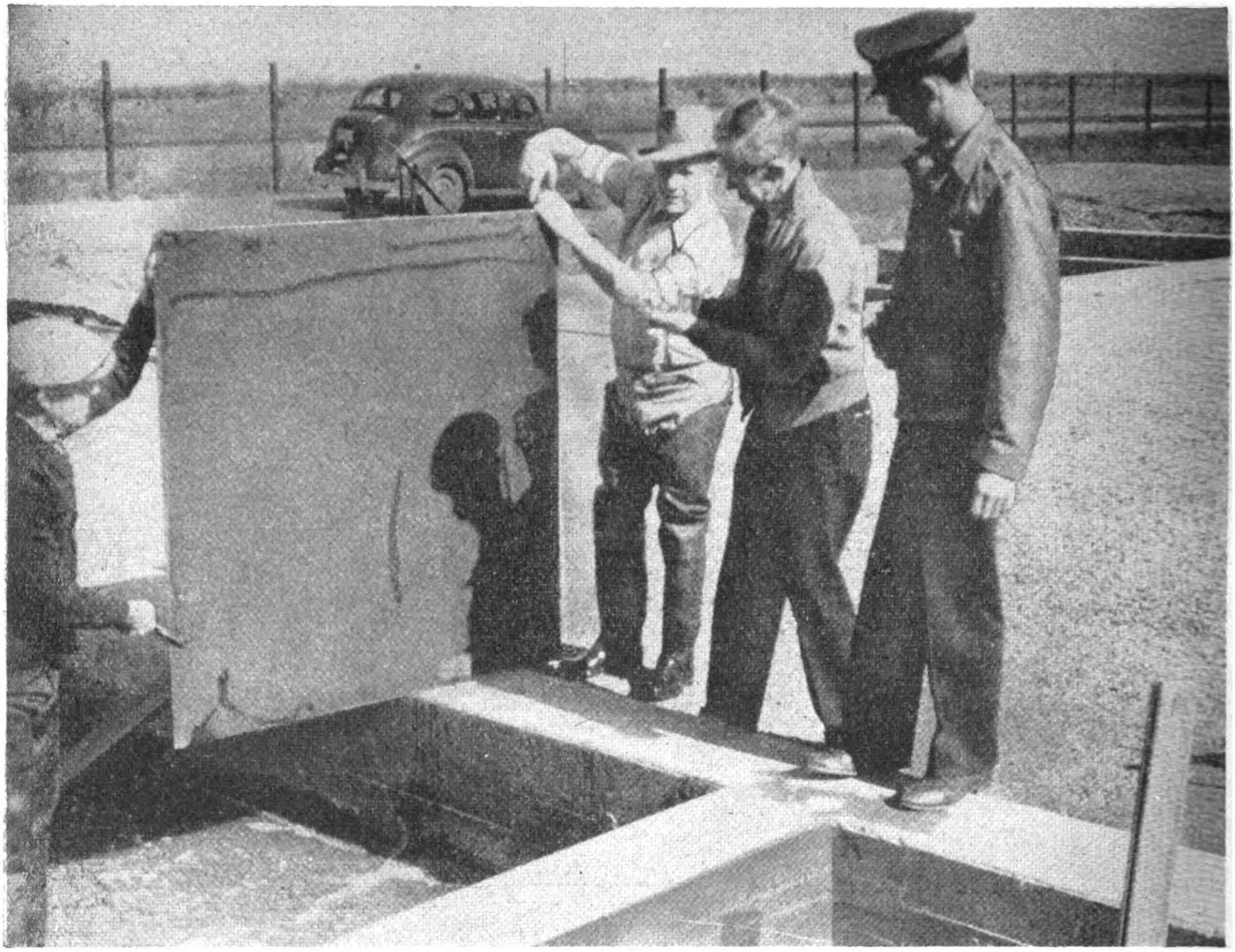


FIGURE 122. *Asbestos plate from contact aerator, showing thin film.*

FIGURE 123. *Cleaning plates with compressed air.*

d. INTERMEDIATE AND FINAL SETTLING. Sludge is drawn from intermediate and final-settling tanks at 4-hour intervals and returned to raw-sewage flow. Sludge must not become septic; sludge hoppers are squeegeed at least once each day. Influent and effluent channels are brushed, and walls and walkways are washed down at least once each day. If two or more intermediate-settling tanks are used, only enough are kept in service to provide 1½ hours detention (¾ hours with recirculation) at average rate of flow.

122. Control Tests

DO determinations on each aerator section and on the intermediate and final effluents are made at least once each shift. The inhibitor is used as shown in paragraph 166. BOD and suspended-solids determinations are made on composite samples of raw sewage and primary, intermediate, and final effluent. Frequency of sampling, as well as other tests, are made as shown in section XVII, chapter 4. Figure 124 shows results of BOD, suspended-solids, and DO tests for a properly operating contact-aeration plant. If recirculation is employed, BOD and suspended-solids in first-stage aerator, intermediate-settling tank, and second-stage aerator are normally lower because of dilution.

123. Records of Operation

a. DAILY. The following is recorded on daily operating records:

(1) Time of operation of blowers.

(2) Air pressure.

(3) Estimated or metered volume of air used daily.

(4) Estimated quantity of sludge returned to raw sewage flow.

(5) Quantity and method of recirculation.

(6) Time units taken out of and returned to service.

(7) Results of DO and other analytical tests.

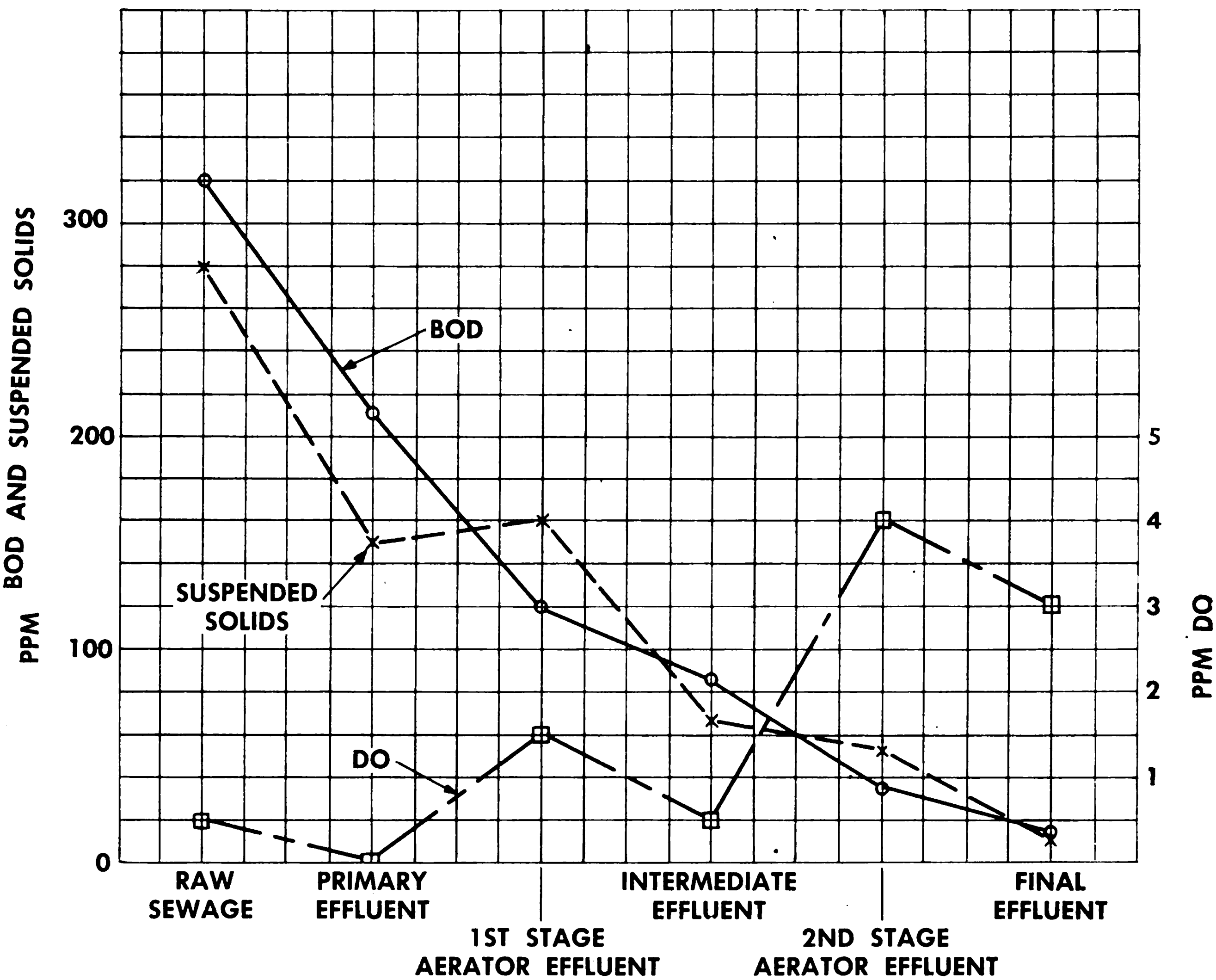


FIGURE 124. *Typical BOD, suspended-solids, and DO results.*

(8) Remarks as to operating conditions, including appearance of plate growths, presence of odor, or clogging of air-distribution system.

b. MONTHLY. Items 3 to 8 inclusive, in *a* above, are reported on monthly operating log.

Section XIII. INTERMITTENT SAND FILTERS

124. Purpose

Sewage is filtered through sand as a secondary treatment following primary settling or for further treatment following other secondary processes. Discharge to natural sand deposits is sometimes used as a method of disposal whereby sewage passes into the ground water and there is no surface effluent. Sand filters with underdrains usually produce an effluent which is clear, sparkling, low in suspended solids and BOD, and highly nitrified. The filter removes suspended solids mechanically by straining and oxidizes organic matter by action of bacterial films on the sand grains. Figure 125 shows an installation with intermittent sand filters.

125. Type of Construction

a. MATERIAL. If adequate natural sand deposits are available, sand filters are developed by using the topsoil to form embankments around the filters and to support and cover the pipe lines carrying sewage to the filters. Clean quartz sand is most desirable for these filters. The size and uniformity of sand particles affect operation: sand too fine gives low filtering rates, clogging the beds; sand too coarse permits high filtering rates, allowing fine organic material to penetrate deep into the bed. Best results are obtained with sand having an effective size between 0.20 and 0.36 mm and a uniformity coefficient less than 4.0.

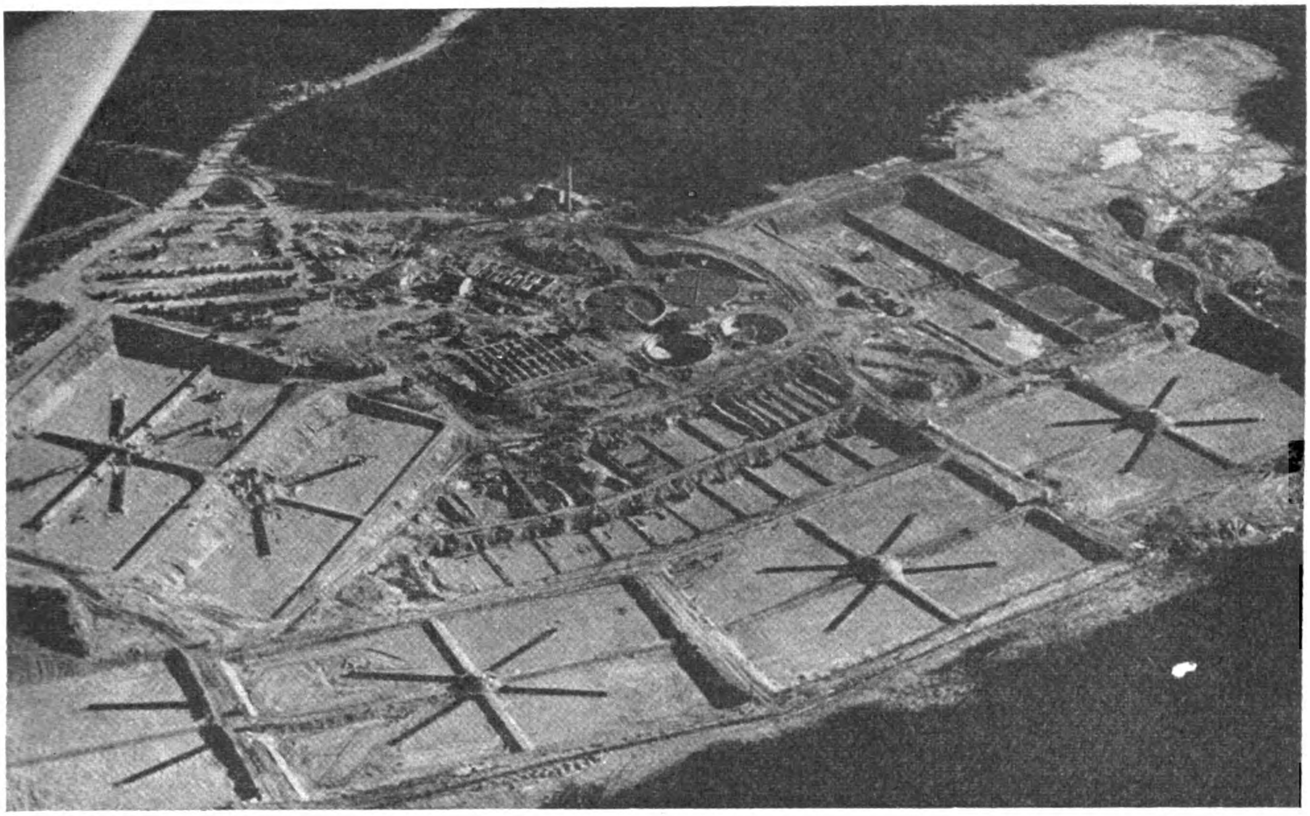


FIGURE 125. *Aerial view of sewage treatment plant with intermittent sand filters.*

b. UNDERDRAINS. Underdrains required in natural sand deposits or laid in artifically constructed filters are placed 3 to 4 feet below the surface and 3 to 4 feet apart. They are usually of vitrified tile 4 to 6 inches in diameter laid with an open space of 3/8 inch between spigot and bell. The drain is surrounded with two or three layers of different-sized gravel to prevent the passage of sand into the lines; they usually lead through a single outlet to a water course.

c. DISTRIBUTION. In small plants, distribution to beds is usually by manually-operated shear gates in manholes or boxes. For larger plants, dosing tanks are used with manually or automatically-controlled gates or siphons. Filter surfaces are level and distribution is made from outlets discharging on a paved area at the sides or corners of the beds or by troughs laid on the bed with openings at several points. Figure 126 shows sand filters with diversion box and distribution trough. If discharge is at one point, some arrangement to reduce flow velocity is necessary to prevent scouring of sand. This may be done by stones or concrete blocks set so the flow is impinged. Another method uses a shallow stilling well at the point of discharge.

126. Operation

a. RATE OF DOSING. The rate of dosing a sand filter depends upon the pretreatment given the sewage or the amount of suspended solids contained and size and uniformity of sand grains. As the quantity of suspended solids lessens and sand becomes larger and more uniform, the allowable rate of application increases. The following rates of treatment can be expected under average conditions.

	Gallons per acre daily	*Persons per acre*
Little or no preliminary treatment	20,000–75,000	400–1,000
Settled sewage	50,000–125,000	500–1,500
Effluent from trickling filters or activated sludge	100,000–800,000	1,000–10,000

b. RATE OF APPLICATION. The size of individual doses, rate of application, and frequency of dosing vary considerably. Rate must be high enough to cover the entire bed quickly to a 3-inch average depth. Dosage varies from one dose every other day to three daily. The bed must drain thoroughly and the flow in the underdrains from the filter must be very low before it is used again to permit thorough bed aeration.

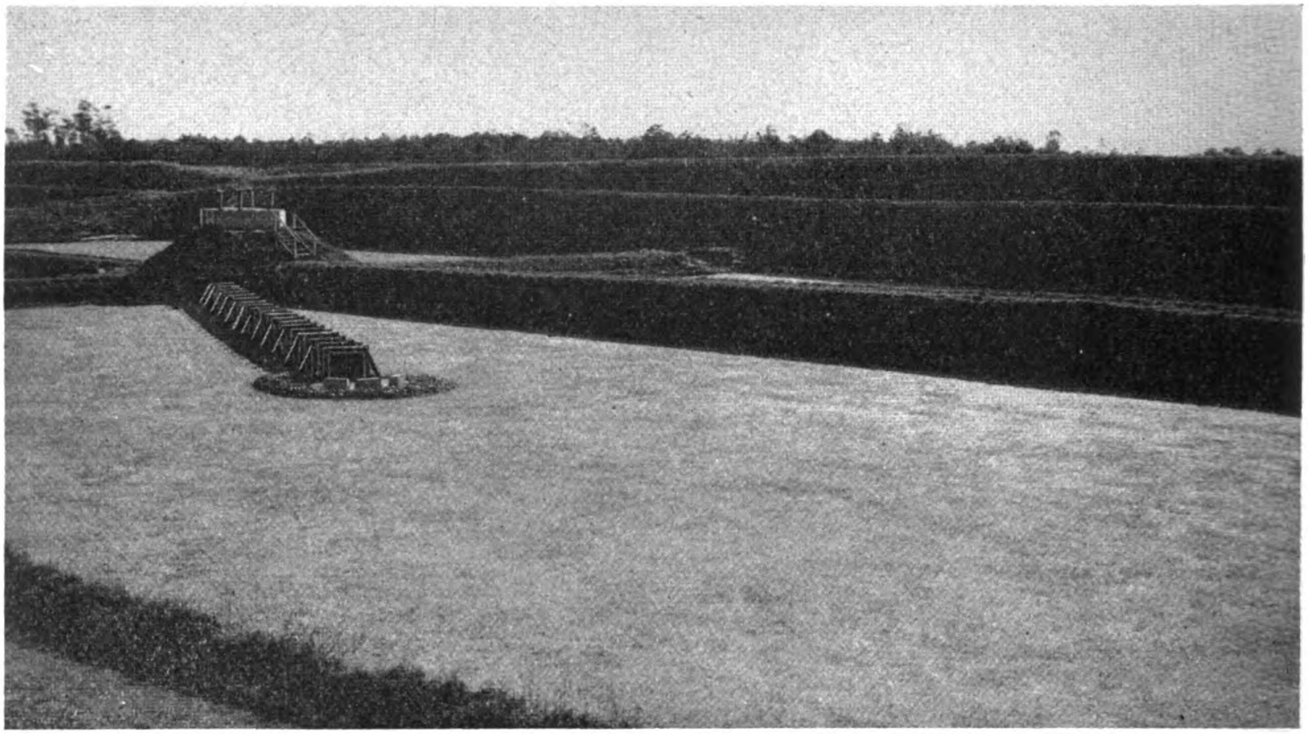


FIGURE 126. *Sand filters with diversion box and distribution trough.*

c. WINTER OPERATION. In cold climates, freezing may seriously interfere with sand-filter operation. To avoid such difficulty, the bed may be furrowed every 3 feet into ridges about 10 inches high; ice is then supported by the ridges. A method which simplifies subsequent cleaning is leading mounds of material from the last fall cleaning about 1 foot high and 4 to 8 feet apart to support the ice. The mounds are completely removed for spring cleaning.

127. Cleaning

When pools of sewage remain on a filter several hours after dosing, the filter should be taken out of service until dry and then cleaned. When settled sewage is applied, a mat that dries, cracks, and curls forms on the surface which is readily removed with forks or rakes. When the effluent from secondary treatment is applied to sand filters, a mat may form slowly or not at all, and clogging may take place between the top sand grains. Cleaning is necessary at less frequent intervals. About ½ inch of the top sand must be removed with shovels or hand scraper when required. Figure 127 shows a sand filter being cleaned.

a. REMOVING THE MAT. Hand removal is customary, but at plants without underdrains tractor-drawn scoop type scrapers may be used. Heavy equipment cannot be used on beds having underdrains because the tile will be crushed.

b. LEVELING THE SURFACE. After the surface has been cleaned, it should be loosened with a garden rake and leveled to grade. Harrowing a sand filter should be resorted to only for deep clogging because it fouls the sand to greater depths.

c. ADDING SAND. New sand must be added periodically to maintain proper sand depth over the underdrains. For filters built in natural sand deposits of considerable depth without underdrains, sand need rarely be added except for small quantities required for leveling.

d. PONDING. Sand filters must not be allowed to pond or be used as lagoons after clogging except in extreme emergency because solids continue to accumulate on the surface until it becomes difficult to restore the filter to normal condition.

128. Dunbar Filters

Dunbar filters are shallow, artifically-constructed filters of coarse sand supported on several layers of graded gravel.

a. CONSTRUCTION. The layers of material are constructed approximately as follows:

(1) Sixteen-inch layer sand, $\frac{1}{25}$ to ⅛ inch (1 to 3 mm).

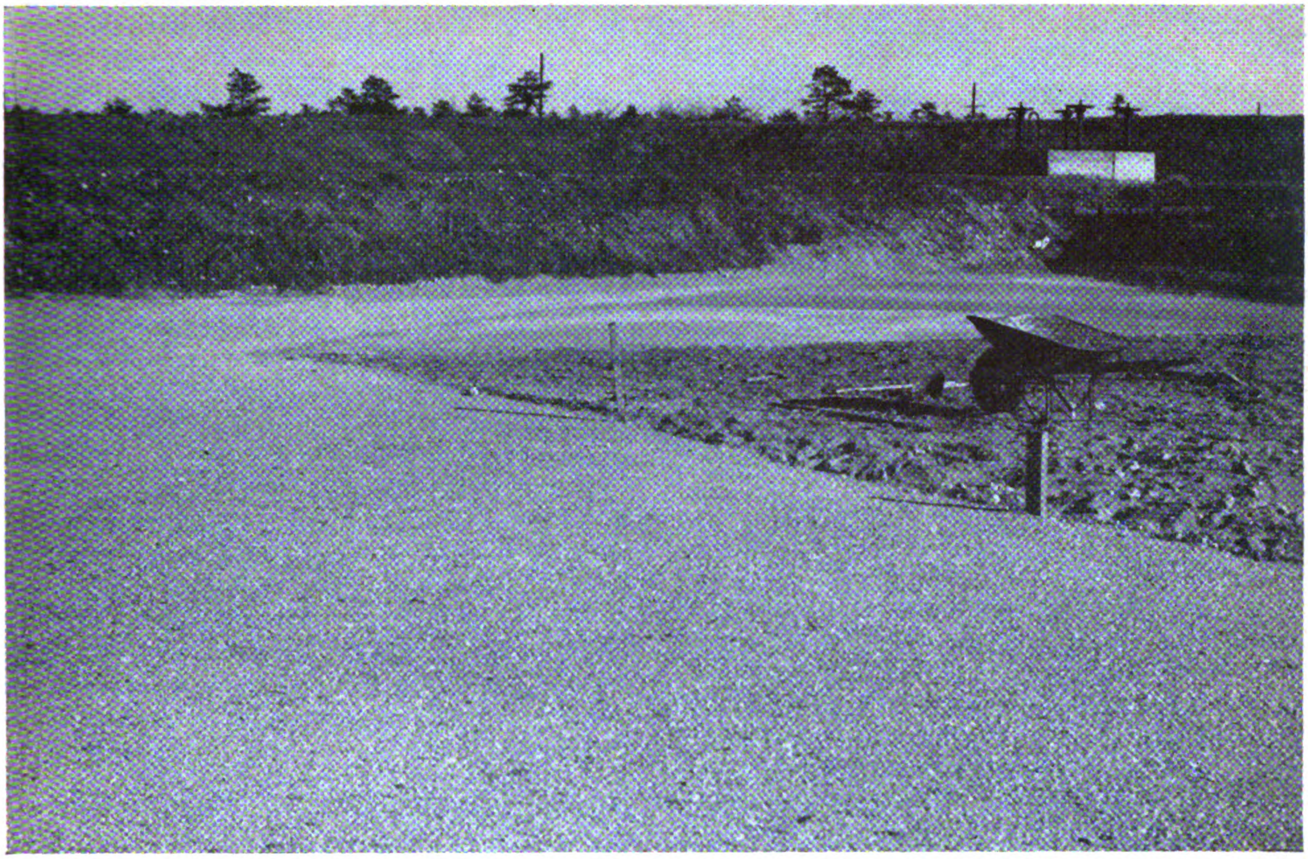


FIGURE 127. *Cleaning and leveling sand filter.*

(2) Four-inch layer gravel, ⅛ to ⅜ inch (3 to 9 mm).

(3) Four-inch layer gravel, ⅜ to 1½ inch.

(4) Twenty four-inch layer gravel, 3 to 6 inch.

Note: This sand is quite coarse compared to an effective size of 0.2 to 0.35 mm recommended for intermittent sand filters.

b. OPERATION. Experiments show that this filter can handle up to 2-million gallons per acre per day. Best results for Imhoff tank effluent is about 1.3 mgad. The filter is dosed on alternate days, the average rate of application per day is about half the above rates or about 0.65 mgad. Dunbar filters are dosed from a trough in the center of the bed and sewage leaves the trough through holes in the sides or by overflow. Dosing is continued until the bed clogs, indicated by the sewage standing several inches over the bed; the bed is then rested and cleaned. At the recommended dosage, these filters usually require cleaning after filtering approximately 8-million gallons per acre. The cleaning consists of raking up and removing the mat of organic matter formed on the surface.

c. QUALITY OF EFFLUENT. At the recommended dosage this type of filter produces an effluent containing considerable dissolved oxygen and low in suspended solids and BOD.

129. Records

a. DAILY. The following daily records are maintained:

(1) Time of starting and stopping application to each filter.

(2) Depth of application to each filter.

(3) Number of filters out of operation for resting, cleaning, sand removal, or replacement.

b. MONTHLY. Monthly operating logs contain the following data:

(1) Total number of filters in service.

(2) Total applications daily and monthly.

(3) Total number of filters out of service.

(4) Results of tests for suspended solids, BOD, and relative stability of filter effluents (not applicable to filters without underdrains).

(5) Remarks on operating conditions, filter clogging, cleaning, sand removal, and replacement.

Section XIV. LAGOONS

130. General

Sewage effluent lagoons or ponds, also known as *holding and evaporating ponds*, oxidation ponds, or percolation beds, under certain conditions offer economical sewage treatment and disposal with a minimum of initial materials. However, their use is limited to isolated and protected locations with available land and suitable climatic conditions. Their use is particularly suited to warm, dry climates such as desert areas. Certain types are used for effluent disposal where there are no streams. Their ability to absorb shock loads and ease of operation and maintenance make them desirable treatment units.

131. Type of Construction

Considerable variation is possible in the construction of lagoons. Where terrain is favorable, advantage is taken of natural hollows or dry lakes into which the settled sewage can flow. Artificial structures have earthen dykes surrounding connected areas to allow operation in series, in parallel, or in combination of the two. The water in the lagoons usually is not over 3 feet deep. When the wind is strong enough to prevent surface scum, inlet or effluent baffles may not be required. Distribution baffles are shallow so water velocity under them is not rapid enough to scour the pond bottom; overflow outfall weirs of maximum length are desirable. Structures carrying effluent from one lagoon to the next usually provide some turbulence and aeration. Some ponds are designed to provide a minimum of 30 days detention of the average daily flow. In determining this detention period, only the top 2 feet of water in ponds under 10 acres in area and only the top 3 feet in ponds over 20 acres in area are considered.

132. Treatment

Primary-settling is the minimum treatment given sewage before it is put into the lagoons. Otherwise, except under unusual conditions, sludge deposits build up in the influent section of the lagoons, not only causing septic conditions during digestion but also making periodic cleaning of the inlet lagoon necessary.

a. Percolation. Considerable sewage volume may be lost by percolation into the ground from lagoons just put into service or located above coarse sand or gravel formations. Unless the formation under the lagoon is porous, the floor soon clogs with sediment, eliminating or greatly reducing the sewage lost by percolation.

b. Evaporation. Loss of sewage volume by evaporation depends on area of water surface and climatic conditions. At some installations in dry areas, this loss equals the entire flow.

c. Settling. Sewage effluent is improved during detention by sedimentation of additional suspended solids.

d. Biological action. Biological life developed in the lagoons uses the organic and mineral matter in the sewage for food to produce more stable products. These products often stimulate abundant growth of algae and other vegetation. Solution of oxygen from the atmosphere, and ability of vegetation to produce oxygen under sunlight help maintain aerobic lagoons. In a properly constructed system, aerobic conditions establish themselves after a short detention period. The lagoons develop an odor similar to fresh-water ponds in wooded areas. During cold or cloudy weather, treatment becomes much less effective because algal oxygen production is retarded.

133. Operation

In warm, clear weather, the lagoon system operated normally and in series shows continuous improvement in quantity of the successive effluents. Dissolved oxygen appears and may increase to supersaturation. The pH increases until it is definitely in the alkaline range; BOD and suspended solids decrease. Operation and maintenance of effluent lagoons is simple. Inside wall surfaces must be protected from collapse or wave erosion, usually by adequate fill. Mosquito breeding can be controlled by keeping lagoon shores clean and by alternately raising and lowering the water level about 6 inches every 10 days during the breeding season. Raw or digested sludge, or supernatant, must not be discharged into a lagoon system used for holding and treating a sewage effluent.

134. Control Tests

Control tests are made at least weekly to determine efficiency of the lagoons and condition of final effluent if the ponds overflow. When there is no overflow, determination of either pH or DO or both is adequate. Where facilities are available, tests include determination for BOD and DO at the effluent of each lagoon in series. Figure 128 shows a typical curve of BOD and DO concentrations in a series of eight lagoons.

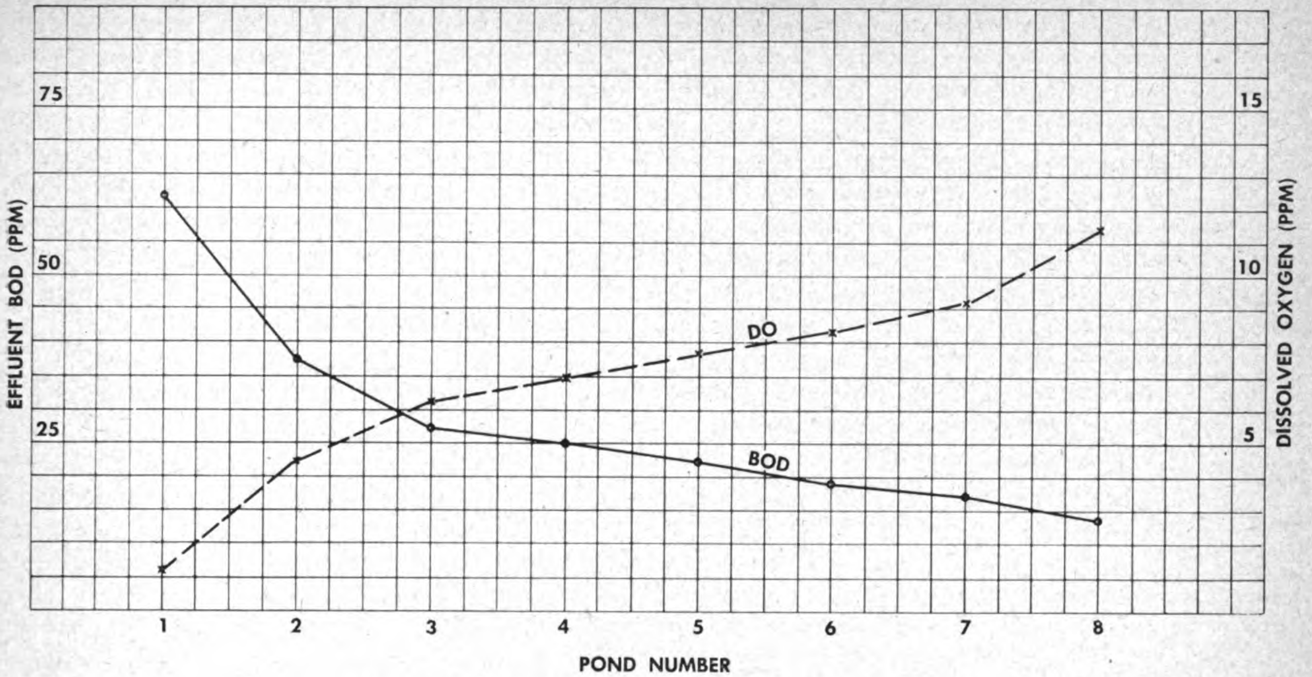


FIGURE 128. *BOD and DO concentration in effluent lagoons.*

135. Reports

The following data is reported on monthly sewage logs:

a. Estimate of quantity of overflow from lagoons.

b. Dissolved oxygen, pH, and relative stability of pond effluent.

c. BOD and suspended solids of pond effluent.

Section XV. CHLORINATION

136. Use of Chlorine and Available Forms

Chlorinating facilities have been provided at many Army treatment plants for disinfecting final effluents, controlling odors, and other operations. Because cost of chlorine is frequently a large item in sewage treatment plant operation, sewage should be chlorinated only in controlled amounts for definite purposes. Indiscriminate chlorination of sewage merely because facilities are provided or as a substitute for correct operation is not practiced. Chlorine may be obtained in the following forms:

a. LIQUID. As a liquid in 150-pound or 1-ton pressure containers. This is the usual form used in sewage chlorination.

b. CHLORIDE OF LIME. Chloride of lime (approximately 35 percent available chlorine) may be used as a general chlorinating agent if application is made by hand. High-test or grade A calcium hypochlorite may also be used.

c. SODIUM HYPOCHLORITE SOLUTION. Sodium hypochlorite (10 to 15 percent available chlorine) is perferable for use with pump type feeders because chloride of lime tends to plug such equipment. Sodium hypochlorite solution is obtainable in 5-gallon carboys from jobbers of commercial laundry supplies. The solution is relatively unstable and should not be stored longer than 1 month before use.

137. Chlorine Equipment

Gas-feed machines, described in TM 5–660 (when published), are manufactured in several types including pulsating, vacuum, and solution feeds. The vacuum-pressure type is preferable since leaks in equipment do not result in chlorine loss. Chlorinators are available with manual, semiautomatic, or fully automatic controls. In the semiautomatic type, the rate of feed is set by hand but the equipment is automatically turned on and off by electric or hydraulic controls. This type is usually used with automatically-controlled sewage pumps. In the fully automatic type, the rate of feed is automatically controlled in proportion to the rate of flow of sewage being chlorinated; this type is not ordinarily warranted for sewage treatment since chlorine demand of the sewage also fluctuates and the rate of feed must be further adjusted.

a. MANUFACTURER'S INSTRUCTIONS. The manufacturer's instructions are usually very complete

and must be closely followed in operating chlorination equipment. A copy should be available at all times at the sewage treatment plant. Operating procedures are also given in TM 5–660.

b. TEMPERATURE. Temperature in the chlorinating room is maintained at approximately 70° F.; chlorinator and gas line cannot be exposed to cold drafts from open windows. When chlorine is drawn from cylinders, evaporation takes place which cools the liquid and gas. If the chlorinator and lines between cylinder and chlorinator are exposed to colder temperatures than the cylinder, chlorine condensation takes place within the lines or machine. Cylinders must not be placed near heaters or in direct sunlight. Chlorine gas lines are kept high with a constant upward slope from the cylinder to the chlorinator.

c. WITHDRAWAL FROM CYLINDERS. To prevent excessive cooling and pressure reduction in the cylinders, the rate of chlorine withdrawal from each 150-pound cylinder must not exceed 35 pounds for 24 hours. Two or more cylinders must be connected in parrallel if this rate is exceeded. Amounts drawn from a 1-ton container may be as high as 400 pounds per day.

d. USE OF SCALES. Most installations have platform scales for weighing chlorine cylinders to check rate of application as indicated by the chlorinator for any run of constant feed. Scales are also used to check the total chlorine used daily and determine when cylinders are completely emptied.

e. HYPOCHLORINATORS. Hypochlorinators are useful for feeding small amounts of hypochlorite solution, for emergency chlorination, and for seasonal chlorination at small plants where the cost of gas type machines is prohibitive. The quantity of available chlorine that can be used is limited and the cost of this form is high compared to liquid chlorine.

138. Chlorine Demand

Chlorine applied to sewage reacts with the organic material to form complex chlorine compounds. The amount used in these reactions constitutes the chlorine demand of sewage. As the chlorine dosage is increased, free chlorine, hypochlorous acid, and chloramines in excess of chlorine demand remain in the sewage. These constitute the chlorine residual and are the principal agents in bactericidal action. Chlorine demand of secondary effluents is usually more constant than for raw sewage, although if the plant is operating at peak load or at low efficiency, considerable variation in the demand occurs. Chlorine demand varies with the strength of sewage and its degree of septicity or staleness. Both the chlorine demand and chlorine residual are expressed in parts per million (ppm). Method of testing for chlorine residual is given in paragraph 164. Figure 129 shows typical curves of variations in sewage flows, chlorine demand, and chlorine application.

139. Calculation of Chlorine Feed

The number of pounds of chlorine required to satisfy the chlorine demand and provide a specific residual is determined by the formula: (ppm chlorine demand + ppm desired residual) 8.34 = pounds chlorine per million gallons. Chlorinators are set to deliver a definite number of pounds per 24 hours. To set the chlorinator properly, rate of flow in million gallons per day (mgd) at the particular time period must be known. The setting is determined by multiplying this rate in mgd by pounds chlorine per million gallons. Chlorine feed can be regulated by frequent determination of the residual if the variation in demand is not great.

140. Postchlorination

Chlorination of sewage plant effluents (postchlorination) is done only when necessary for disinfection and for reduction of oxygen demand in the receiving stream. Determination of necessity is made in accordance with policy set forth in TM 5–600.

a. DISINFECTION. Disinfection is required when sewage effluents are discharged to bodies of water used for domestic water supply, shellfish culture, training and recreational activities, and irrigation. Where water supplies are taken relatively near the point of outfall, disinfection of effluent is vitally important. Disinfection may be seasonal, as during the bathing season or periods when troops are using a stream for training. When stream flows are excessive during the spring run-off or a rainy season, disinfection may not be essential because of the dilution factor. Because of constant fluctuation of chlorine demand and sewage flow, the effluent's chlorine residual is determined hourly so rate of feed may be properly adjusted.

(1) Bacterial content of settled or secondary treated sewage effluents is reduced approximately 99.5 percent by chlorination to a residual of 0.3 to 0.5 ppm with a 15-minute contact period. Complete sterilization is not obtained.

(2) Bacteria are killed by chlorine dosages of less than the chlorine demand. However, effective

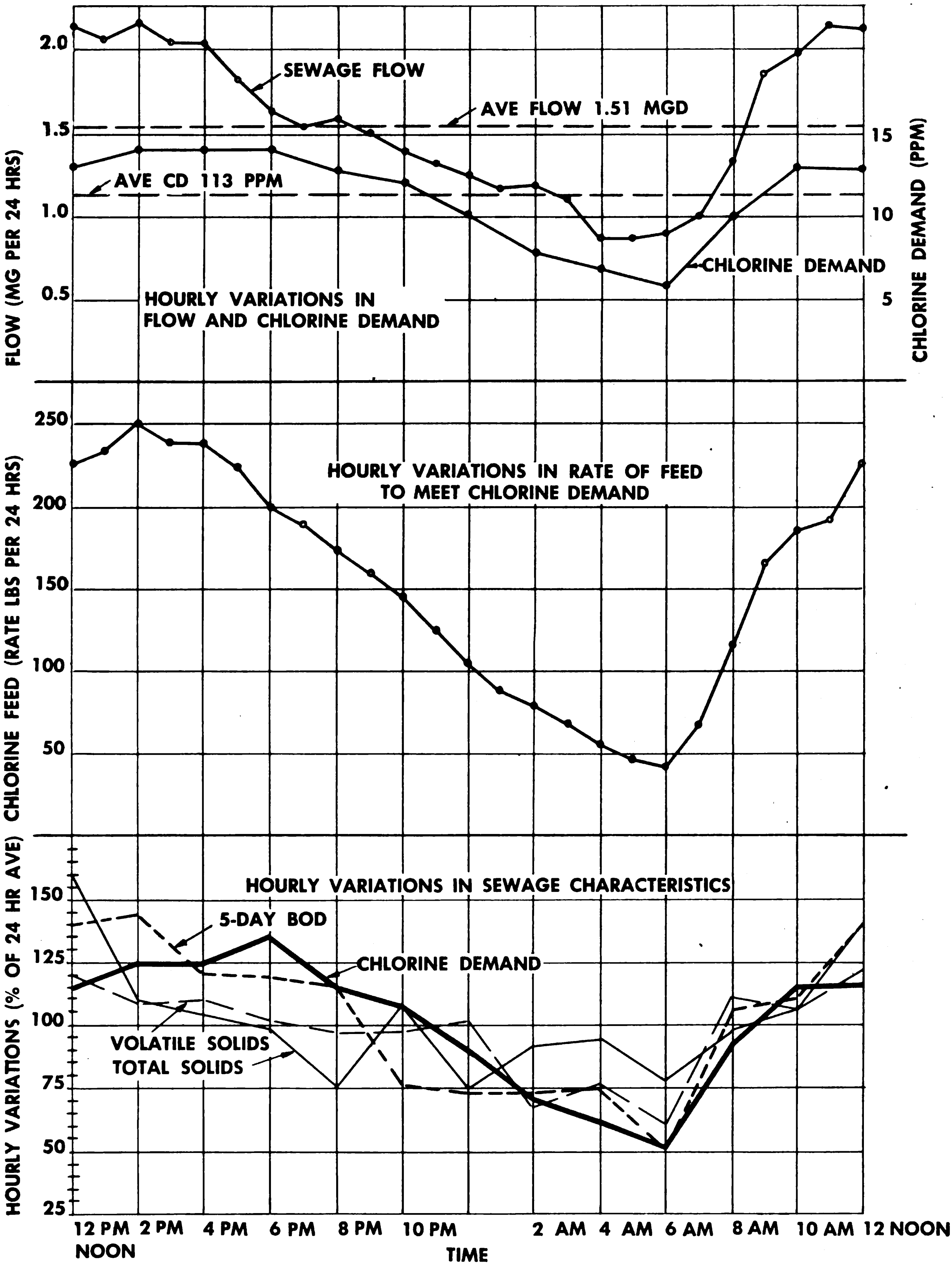


FIGURE 129. *Curves showing variation in sewage flow, chlorine demand, and rate of feed.*

disinfection is best accomplished with the above residual.

(3) The contact period of 15 minutes is necessary to provide time for contact of chlorine and organism either in a separate contact chamber, baffled to prevent short-circuiting, or in the outfall sewer if it is long enough. Figure 130 shows a contact chamber and baffles. The hose in the foreground connects the chlorine diffuser to the chlorinator.

(4) Settled solids must be frequently removed from contact chambers to eliminate excessive chlorine demands.

b. Reduction of effluent BOD. (1) *Amount.* Each ppm of chlorine added to sewage effluent reduces the BOD in the stream to which the effluent flows by 1 to 2 ppm. This BOD reduction is effective in preventing septic conditions or low dissolved oxygen content in a stream where the dilution factor is low. The effect is lost if sludge banks are present in the stream below the outfall.

(2) *Purpose.* Postchlorination is done to protect fish life and prevent nuisances. Normally, a chlorine residual of not over 0.5 ppm is effective for stream control although higher residuals may be maintained during extremely low stream flows. However, chlorination for this purpose is not a cure-all for poor stream conditions and cannot replace proper sewage treatment or correct operation.

141. Prechlorination

a. Low flows. When sewage flows are below rated plant design and detention periods in primary-settling tanks are excessive, chlorine may be added at the plant inlet to keep sewage fresh and prevent odors. The amount of chlorine required varies with the septicity of the raw sewage. Partial

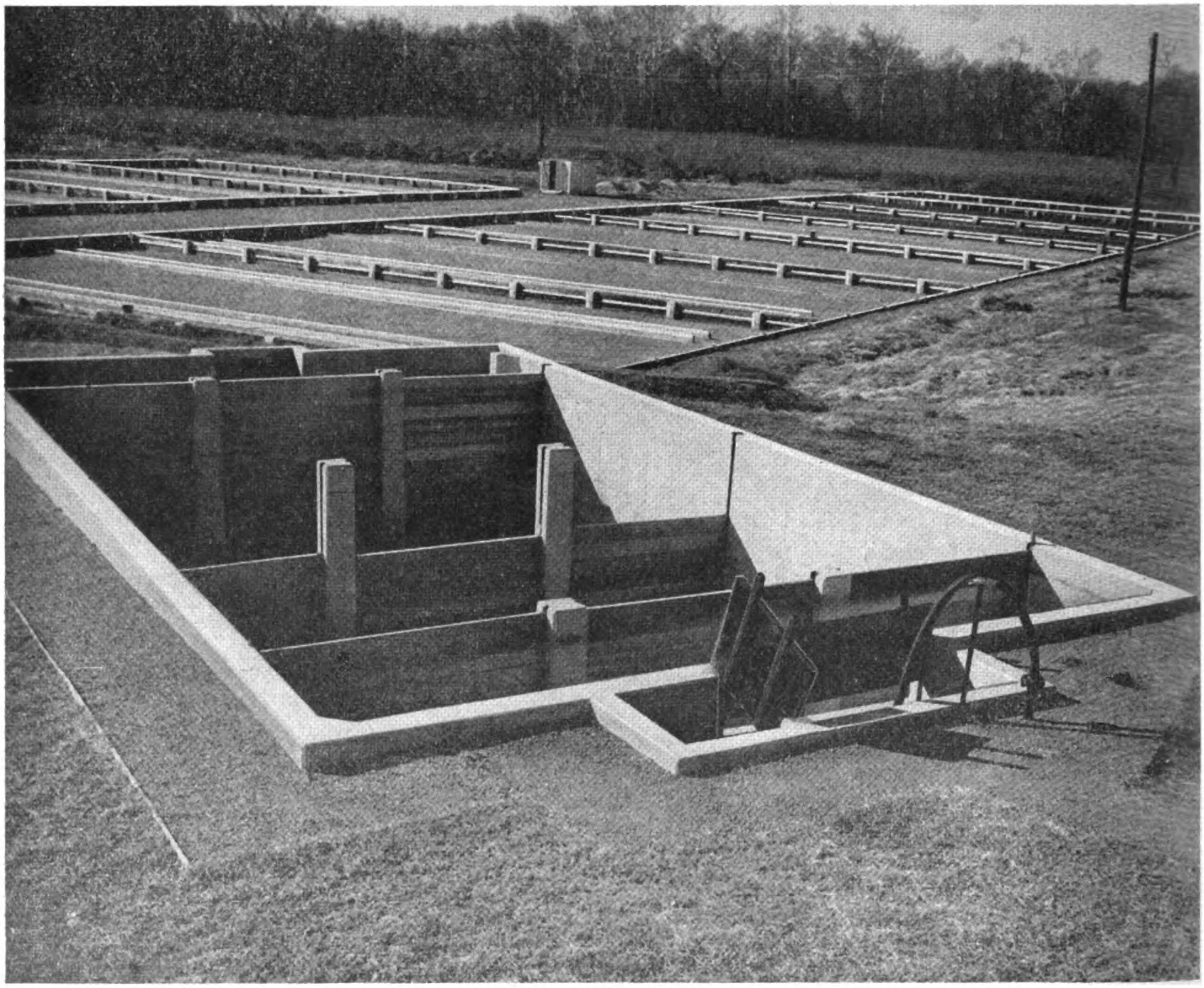


Figure 130. *Chlorine contact tank.*

chlorination up to 5 ppm applied is usually effective; chlorination to a residual is not usually required. Hydrogen sulphide gas is acted upon immediately by chlorine.

b. Odors. Odors may be particularly objectionable from fixed-nozzle sprinkling filters. Partial chlorination of the filter influent will reduce them. Because constant application is usually not required, prechlorination is done only when the wind carries odors toward inhabited areas.

142. Filter Control

Ponding of trickling filters can often be corrected by applying heavy doses of chlorine to the filter influent. A residual up to 5 ppm applied 3 or 4 hours daily for several days starts the solids sloughing from the stone. This is best done at night when sewage flow and chlorine demand are low. Filter flies can be controlled somewhat by chlorinating to a residual of 0.5 to 1.0 ppm for several hours at 2-week intervals. Decreasing filter efficiency by destroying the bacterial growth must be avoided.

143. Activated-sludge Control

Bulking of activated sludge caused by excessive growths of threadlike fungus can usually be corrected by applying chlorine to the return sludge. The amount required depends on the sludge's solids content. Overchlorination upsets the process and must be avoided.

a. Amount. Chlorination may be started by applying 1 ppm (based on return-sludge flow) and increasing the dosage daily in small increments until slight turbidity is noted in the final tank. Dosage should then be decreased. In most cases the dose does not exceed 8 ppm.

b. Continuous bulking. Where bulking has been continuous, constant application of small amounts of chlorine to the return sludge may maintain a low sludge index; partial prechlorination of the raw sewage may have the same effect.

144. Sewer System Chlorination

Production of hydrogen sulfide and odorous gases, septic action in the sewers, and undesirable fungus growths are corrected by chlorination of the sewage at a manhole or in a pumping station. Chlorinating sewage in Army systems is normally not justified. Such chlorination cannot replace a regular sewer inspection and cleaning program.

145. Maintenance of Equipment

Maintenance of chlorination equipment is given in detail in TM 5-666.

a. Handling cylinders. Equipment for the proper handling of chlorine cylinders to prevent injury to personnel and damage to the cylinders must be obtained. The 150-pound cylinder can be readily transported by a dolly; 1-ton containers can be removed by rolling, by overhead monorail and hoist, or by a lift truck with suitable skids. Figure 131 shows the design of a post-made two-wheeled cart for handling 150-pound cylinders.

b. Cylinder storage. Cylinders and 1-ton containers are stored under cover and protected from extreme temperatures. Each cylinder has

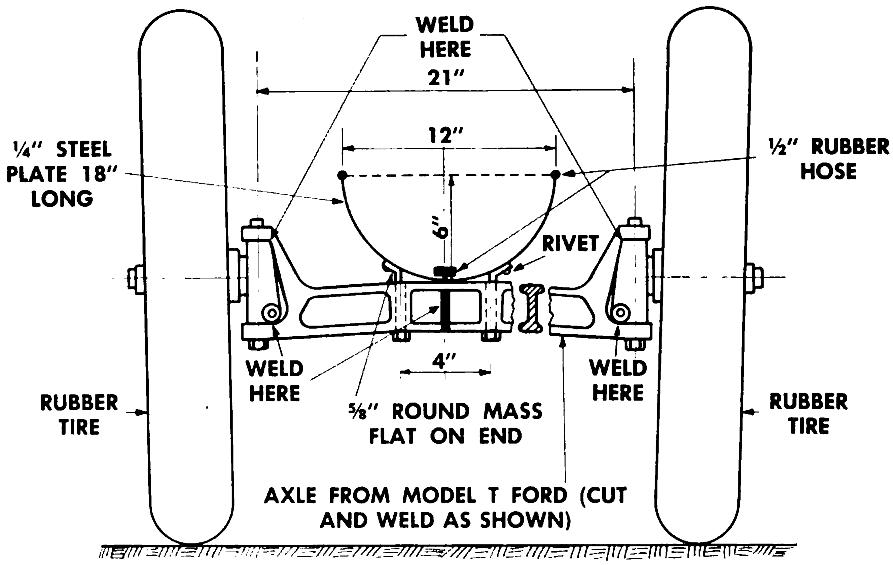


Figure 131. *Cart for handling chlorine cylinders.*

a fusible plug, either in the cylinder body or in the valve, which melts at 157° F. to prevent excessive pressures within the cylinder. Containers exposed to direct sunlight may reach the above critical temperature.

c. CYLINDER SHIPMENT. Cylinders or containers must be completely empty before shipment for refilling. The valve must be tight and capped, and the large steel protective cap must be tightened securely. Shipment of cylinders with damaged valves is illegal unless they are empty. *Do not attempt repair of cylinders.*

d. SPARE PARTS. Spare parts for chlorination equipment should be kept on hand at all times.

e. PAINTING. Exposed surfaces on all steel in the chlorinator room is painted annually with a primer coat and a good machine-enamel top coat to prevent excessive corrosion from chlorine gas.

146. Precautions Against Hazards

Because chlorine is poisonous, precautions must be taken to protect personnel. Operators are trained in proper use of gas masks and methods of stopping leaks.

a. Provide adequate ventilation in the chlorinator room. Since chlorine gas is heavier than air, the ventilation must be done by fans or blowers from the floor level and must be adequate to displace the air in the room within a few minutes. If forced ventilation cannot be provided, place ventilating louvers at floor level. Figure 132 shows chlorine room with power fan properly located.

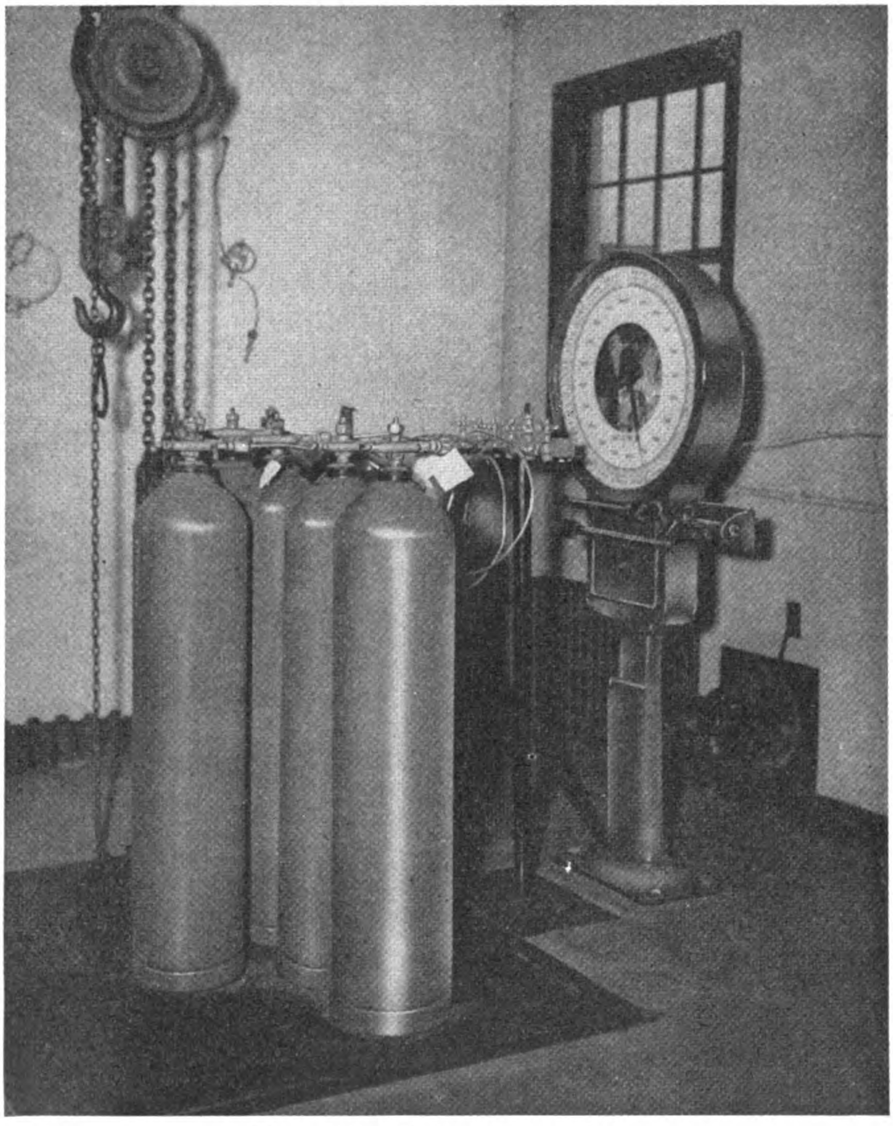


FIGURE 132. *Chlorine room arrangement.*

b. Keep two masks of a suitable type for chlorine outside the chlorinator room. Instruct personnel in proper use of the gas mask. Renew canister at designated intervals. The canister type of mask protects against only 3 percent of chlorine in the atmosphere.

c. Never enter a room in which chlorine is leaking without a gas mask. Where chlorine gas is excessive, enter room only with a mask supplied with air from the outside. Station one person outside to assist in case of an accident.

d. Reduce amount of chlorine in a room by liberally spraying with water.

e. Relieve irritation from inhaling chlorine by inhaling fumes from a pan of hot water to which 6 to 10 drops of tincture of benzoin have been added. This relieves the victim until medical aid can be obtained.

f. See paragraph 23 for further safety information.

147. Records

The following records are entered on the monthly sewage logs:

a. Pounds of chlorine applied daily.

b. Minimum chlorine residual in final effluent in ppm.

c. Remarks indicating any other point of application and estimate of chlorine used at each point.

Section XVI. POLUTION SURVEY OF STREAM

148. Necessity

Sewage treatment must change the character of sewage to make it satisfactory for final disposal. This point of final disposal is often a stream or other body of water. The designing engineer must consider the stream's requirements in the initial design of the treatment works; the operator must learn these requirements from the service command engineer and operate his plant to meet them consistently. To measure the effectiveness of plant operation, a study of stream conditions (stream survey) is required.

149. Survey

Stream surveys are made once each week, preferably on different days by testing on Monday one week, Tuesday the next, etc. Samples are collected shortly after noon on these days. The survey includes the following:

a. Selection of at least three sampling points.

(1) Above the outfall (point of discharge).

(2) Below a point where sewage and water are well mixed.

(3) Several miles below outfall at the critical point for definite flow and weather conditions. This is point of minimum DO, determined by trial and past records.

b. Collection of samples for dissolved oxygen and BOD at each point, using the sampling can shown in figure 139.

c. Immediate addition of reagents for the dissolved-oxygen test up to the point where titration is made, tests being completed later in the laboratory.

d. Water temperature at each sampling point.

e. Stream conditions, such as turbidity, presence of algae or types of fungus, sludge deposits, vegetation on stream bottom, fish life, oil, and odor.

f. An estimate of relative stream flow, such as high, average, and low, or actual flow in mgd when gauging station is nearby.

g. Where sewage effluents are discharged above water supply intakes, stream samples for bacteriological analysis may be required.

Note: Suitable modification of these tests are made when effluents are discharged to lakes or tidal waters. Technical recommendation of higher authority must be obtained.

150. Stream Assets and Liabilities

Every stream or body of water, unless grossly polluted, has certain assets to balance against the liabilities of pollution. All natural waters are somewhat polluted by natural vegetation if not by sewage or wastes. The stream's concentration of dissolved oxygen in the water and its ability to dissolve oxygen from the surrounding air (reaeration) are assets. The BOD, either natural or man-made, is a liability. Removing oxygen from the water to satisfy the BOD is called deoxygenation.

a. Oxygen. Deoxygenation, reaeration, and the dissolved oxygen curve for different points on the stream below the point of pollution are shown by the typical curves in figure 133. Both the deoxygenation and reaeration curve are cumulative. The critical point is the lowest point on the dissolved oxygen curve. At the point of maximum recovery, the deoxygenation curve straightens and the reaeration and oxygen curves tend to run parallel. When the oxygen curve reaches the zero point, septic conditions develop in the stream indicated by odors and fungus growths. This con-

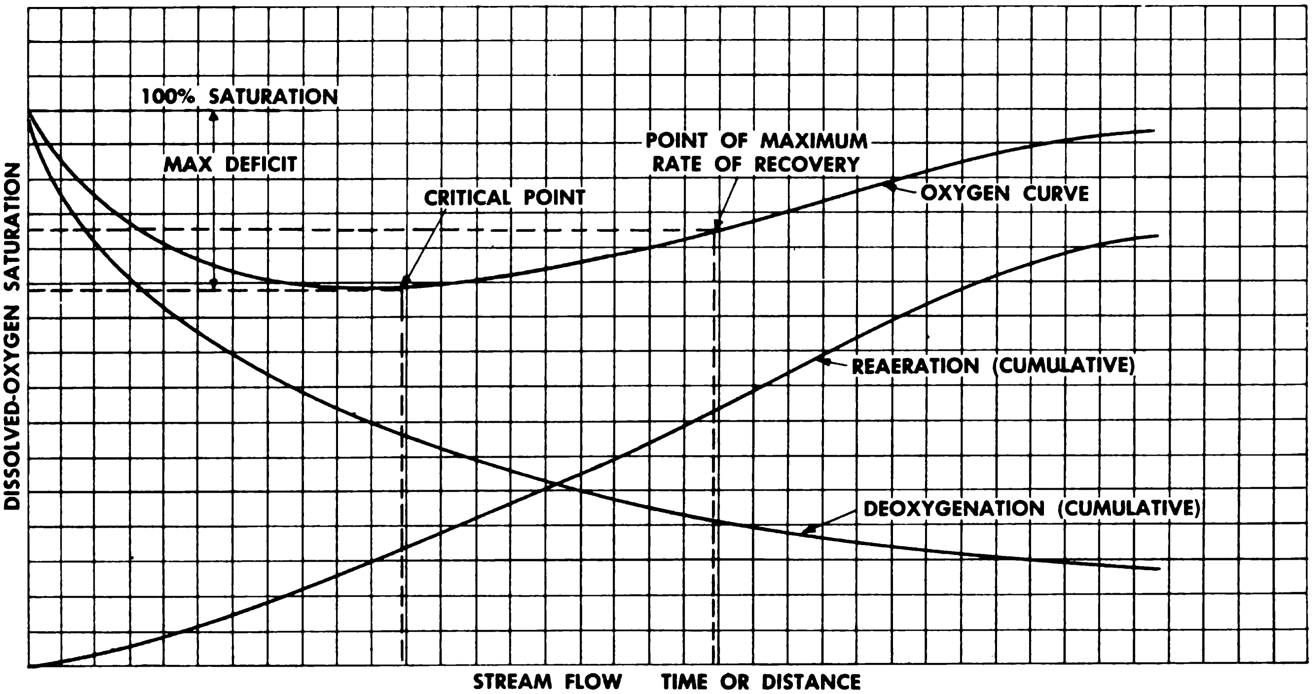


FIGURE 133. *Reaeration, deoxygenation, and oxygen concentration.*

dition must be avoided since liabilities definitely exceeds assets.

b. TEMPERATURE. Critical season of the year is warm weather with the accompanying low stream flow. Oxygen assets are low because the quantity of oxygen that dissolve in water and the rate of solution are indirectly proportional to the temperature. Table III shows the saturation quantities of oxygen in water at different temperatures.

c. ALGAE. Algae produce oxygen and add greatly to the water's assets. Activity is done during daylight hours, oxygen assets being depleted during the night if pollution is great.

d. NITRIFICATION. Algae and other vegetation use the nitrogen, carbon dioxide, mineral, and other compounds in the water and air for growth and development. For this reason, vegetation is usually luxuriant in streams receiving highly nitrified sewage plant effluents. When this vegetation dies and decomposes, it causes natural pollution which often exceeds that added by the sewage plant. Treatment of sewage to the point of high nitrification is, therefore, not always desirable.

151. Sludge Deposits

Solids produced by sewage effluents and those of natural origin tend to settle in the stream bed, forming sludge deposit. Figure 134 illustrates decomposition in the area within and above these deposits. This illustration indicates a definite line between anaerobic and aerobic zones which is not the actual condition since there is a gradual grading between the two. Sludge deposits are stream liabilities.

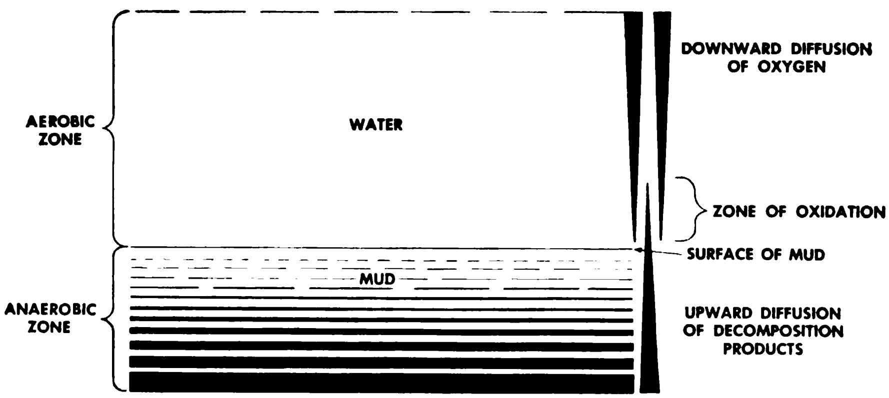


FIGURE 134. *Section of streams sludge deposits showing zones of action.*

152. Corrections

The following general items of sewage treatment are essential for correction of stream pollution:

a. Removal of solids to prevent sludge deposits.

b. Reduction of liabilities by removal of BOD in solids and in solution.

c. Increase in assets by reaeration of plant effluent. Figure 135 shows one method of adding oxygen to plant effluent.

d. Treatment only to the point of low nitrification if algae are detrimental.

e. Under critical conditions, chlorination of plant effluent, which tends to delay deoxygenation.

153. Records

Stream-survey records become important legal documents if damage is claimed because of alleged stream pollution or nuisance. They also help in designing alterations or additions to the sewage treatment plant and controlling normal and supplementary treatment operations. Results of tests and observations are recorded, dated, signed, and safely filed. Summaries of stream surveys (sampling-point distance from outfall, DO, BOD, and percent saturation) are entered on monthly operating log.

Section XVII. SAMPLING AND LABORATORY TESTS

154. Purpose

Sewage is sampled and analyses are made for the following reasons:

a. To determine strength and composition of sewage, permitting the necessary treatment for local requirements.

b. To control the various sewage treatment processes.

c. To determine efficiency of processes and units.

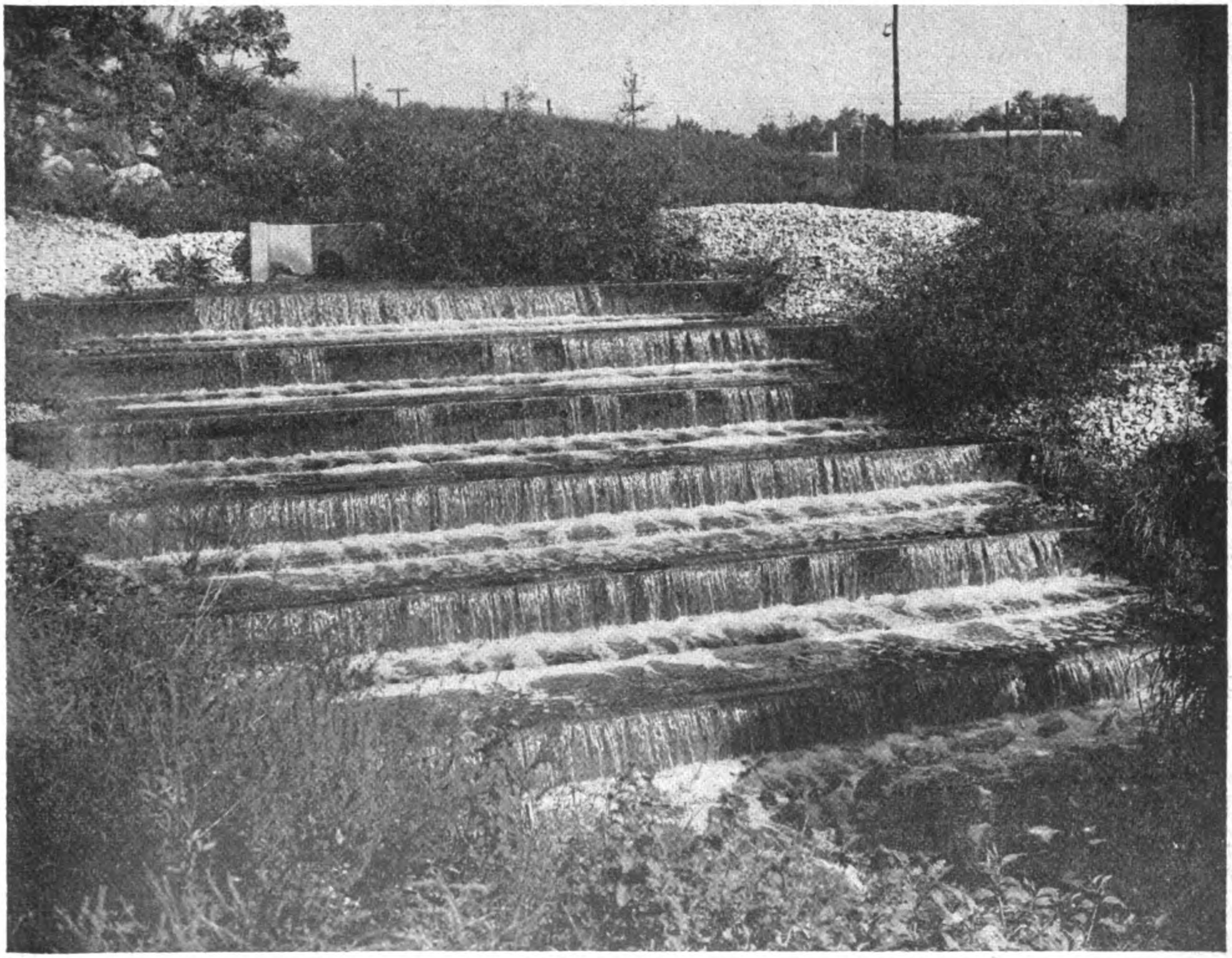


FIGURE 135. *Step aerator for increasing oxygen assets of stream.*

d. To predict effects at the point of final disposal.

e. To determine actual results of treated-sewage discharge.

f. To compile records and data for future use.

155. Representative Samples

Sewage samples must be as near representative of the entire body of sewage as possible. Errors in sampling too often nullify the accuracy of laboratory tests. Because of stratification of solids in conducting channels, rapid changes of sewage character caused by intermittent pumping, and the diverse character of sewage, representative samples are difficult to obtain without careful procedure. Lack of uniformity in sampling leads to incorrect conclusions about the operation of the treatment process. Analytical results are too often accepted without properly considering the limitations of the sample examined.

156. Grab Samples

a. Grab samples are those taken by sampling sewage one time at one point. They cannot give much information about average conditions of the sewage throughout the day but show the momentary condition for immediate control purposes. Some tests require grab samples because rapid changes occur if the time between sampling and testing is long.

b. Grab samples are taken for the following tests:

(1) Dissolved oxygen.
(2) Chlorine demand.
(3) Residual chlorine.
(4) Settleable solids.
(5) Relative stability.
(6) Stream surveys.
(7) Hydrogen ion concentration (pH).
(8) Mixed liquor and return-sludge concentration for activated sludge.
(9) Monthly digester-content tests.

157. Composite Samples

a. GENERAL. Composite samples are made by gathering individual samples at regular intervals over a selected time period which is usually 16 to 24 hours. The time interval for raw sewage or effluents is 1 hour, unless special tests or studies are being made. The volume of each single sample is proportioned to the rate of sewage flow as determined by flow meter, Parshall flume, weir, or other measuring device. A set of well-labeled sampling containers of sufficient size range to accommodate the normal flow variations must be prepared. Individual samples of sewage and effluents are immediately poured into a container large enough to hold the entire amount of composite sample expected over the period (about 1 gal.). These containers are refrigerated or kept cool. Wide-mouth, stoppered glass bottles or covered enameled pails are used. Composite samples are taken for the following determinations:

(1) Suspended solids.
(2) Biochemical oxygen demand (BOD).
(3) Total and volatile solids of sludge.
(4) Grease.
(5) Nitrogen.

b. SAMPLING PERIODS. The sampling period is perferably 24 hours, but must cover at least 16 hours except at plants having shorter periods of attendance. Selection of the period depends on relative rates of flow during the day. Flow and strength are usually uniformly low for an 8-hour period during the night. For 16-hour plant attendance, two samples, each proportioned to the total flow over a 4-hour period, can be taken in place of the hourly samples for this night flow. These samples are taken at the beginning and end of the period and mixed with the hourly samples taken during the day to form a 24-hour composite. If composite-sampling period is less than 16 hours, the length is noted on the monthly operating log.

c. PRESERVATIVES. Preservatives are not used if the BOD test is to be made. Formaldehyde is used for samples collected for grease analyses.

d. SEWAGE AND EFFLUENT SAMPLES. Sewage or effluent samples from channels are taken at two-thirds the depth of the flow at a point free from back eddies. Figure 136 shows the design of a sampler for sewage and effluents; figure 137 shows the sampler used in a channel; figure 138 shows the method for collecting a sample from a tank just ahead of the overflow weir.

e. DISSOLVED-OXYGEN SAMPLES. Sampling for dissolved oxygen requires special procedure and apparatus to prevent an increase in oxygen content through contact with air. Narrow-mouth glass-stoppered 8-ounce bottles should be used with the sampling can. (See fig. 139.) This device can be made at the post utilities shop.

f. SLUDGE SAMPLES. Design of a sampler for collecting sludge samples from digesters is shown in

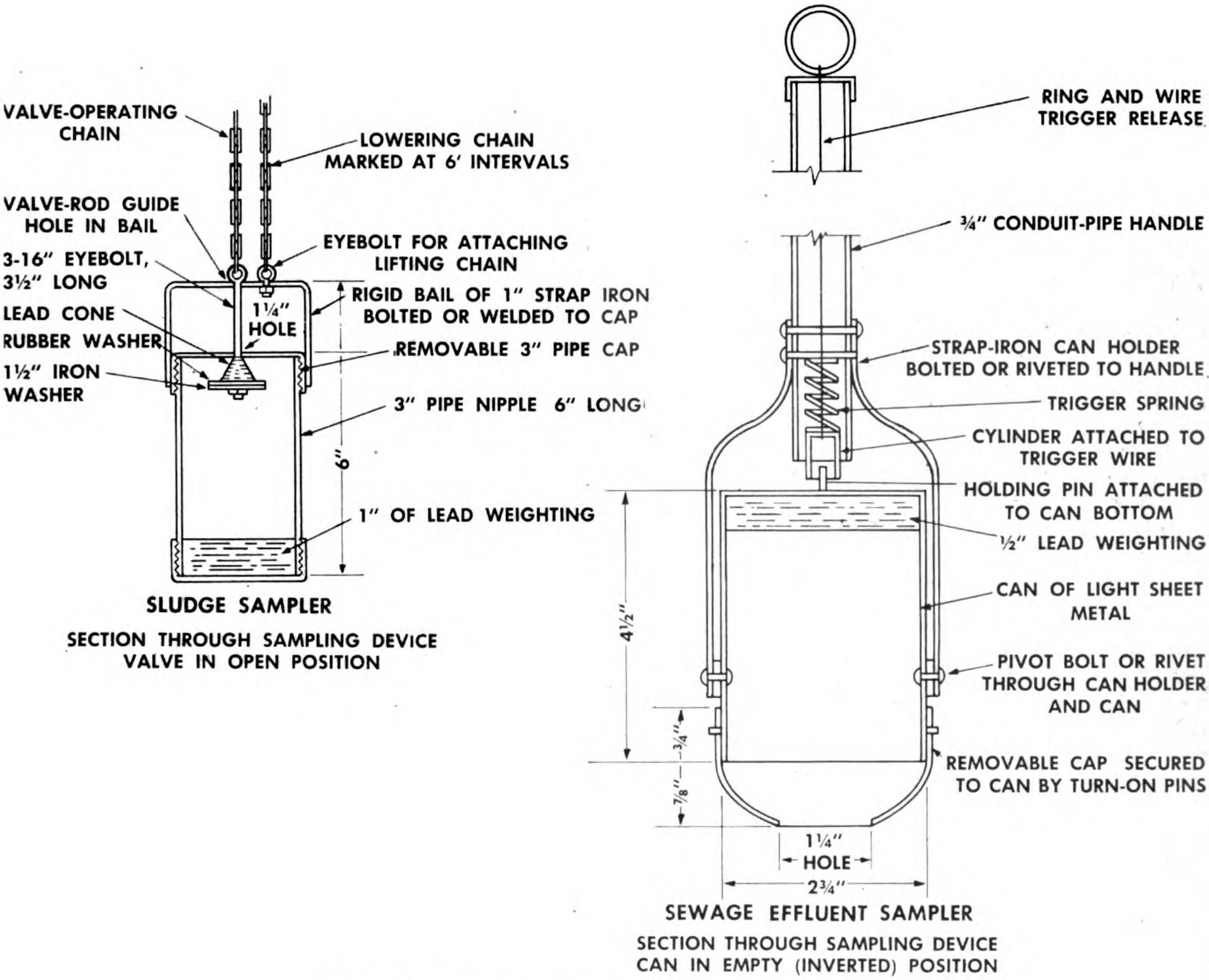


FIGURE 136. *Samplers designed for collecting sewage and sludge.*

figure 136; figure 140 shows the sampler being used in the sampling hole of a digestion tank. The chain is marked to indicate depth at 1-foot intervals. Samples of digester sludge are collected at 3- to 5-foot intervals starting at the top and working down to avoid agitating the sludge from which the following samples are taken. Each sample is poured into an appropriately marked wide-mouth bottle and the sampler thoroughly rinsed before each sample is taken. A pitcher pump with a hose marked at 1-foot intervals may also be used.

g. PUMPING OR DRAWING PERIODS. Composite sludge samples from raw sludge to digester or digested sludge to beds are made up of individual samples collected at regular intervals over the pumping or drawing period. These intervals are spaced to provide for collecting at least 5 or 6 individual samples over any one period. The composite must include all pumping periods for the entire day. Figure 141 shows the method of collecting sludge samples.

158. Schedule of Analyses

The following schedule of sampling and analyses is used at the discretion of the operator and recommendation of the service command engineer. It is suggested as the minimum for proper plant control and adequate records. It shows the type of sample required for the effluents from the various processes and the frequency of collection of grab samples. Composite sewage samples indicated in the tabulation are collected and analyzed at the following time intervals, including Sundays and holidays.

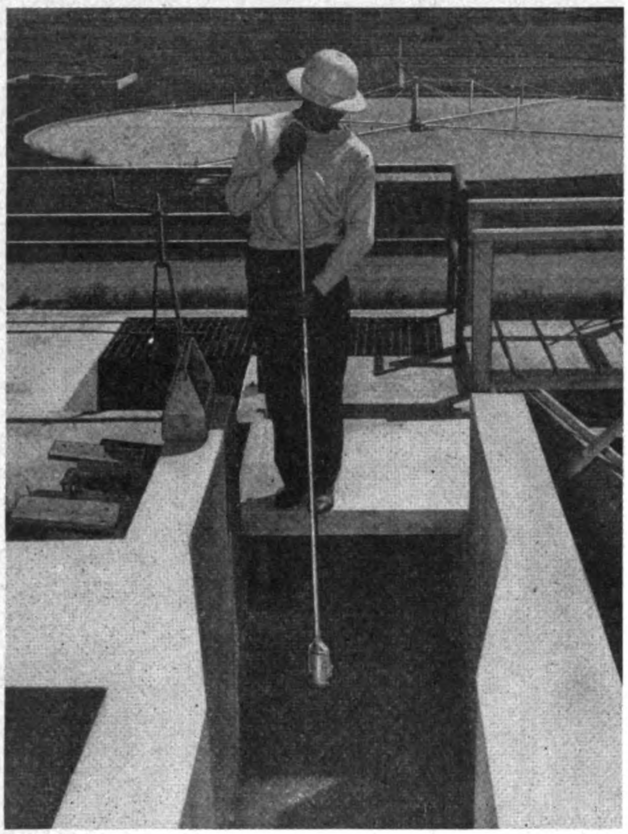


FIGURE 137. *Sample being taken from channel.*

FIGURE 138. *Sampling from tank ahead of weir.*

a. Complete treatment plants are checked as follows:

(1) Post populations over 20,000, daily.

(2) Post populations between 6,000 and 20,000, every 3 days.

(3) Post populations between 1,500 and 6,000, every 6 days.

b. Primary-treatment units only are checked as follows:

(1) Post populations 38,000 and over, daily.

(2) Between 12,000 and 38,000, every 3 days.

(3) Between 1,500 and 12,000, every 6 days.

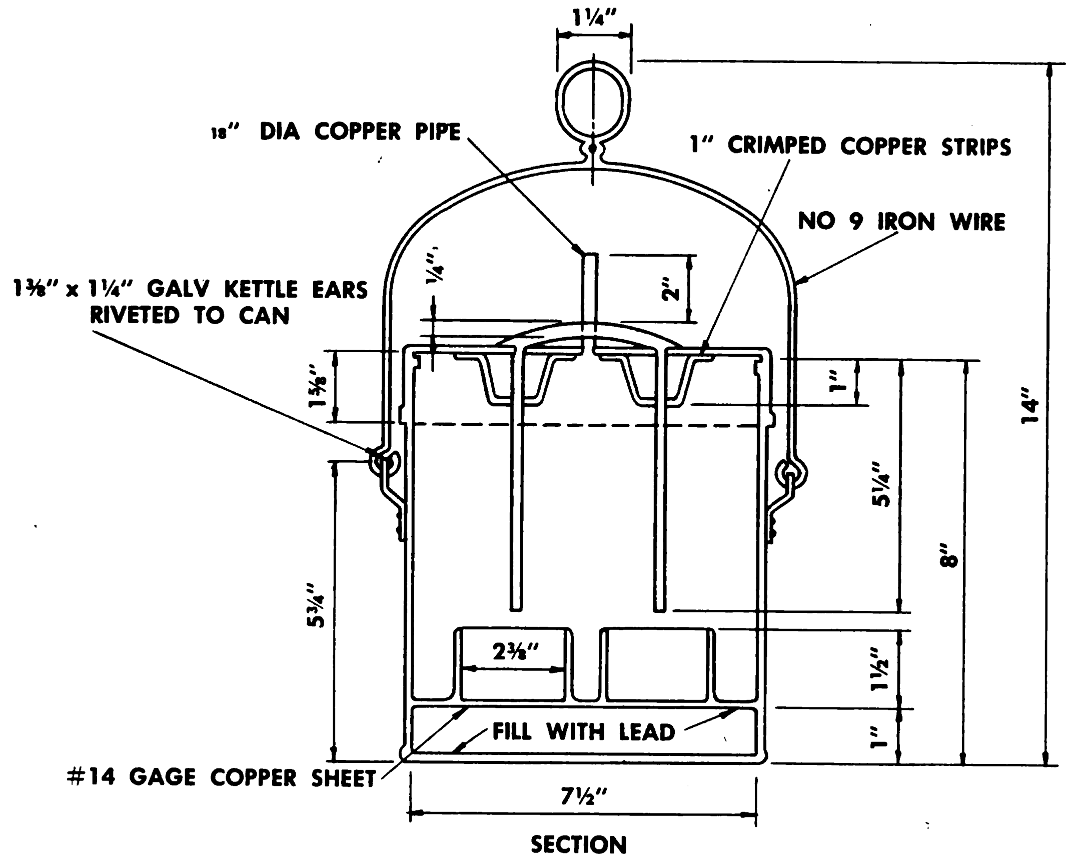
c. Grab-sample sewage tests (par. 156) are made daily.

d. Where BOD and suspended-solids tests are not warranted (posts less than 1,500 population or others on recommendation of service command engineer), the minimum analyses to be made are daily grab-sample tests for settleable solids, pH, relative stability, and chlorine residual where applicable. Single daily sewage samples are taken during peak flow. If taken each shift, average of daily test results are reported on monthly operating logs.

e. Monthly samples are taken from digesters and Imhoff tank sludge compartments.

f. Weekly samples are collected from the stream receiving the plant influent. (See par. 149.)

g. Analyses for grease, alkalinity, total and dissolved solids, nitrogen compounds, carbon dioxide in digester gas, volatile acids in digester, moisture in dried sludge, and other analyses common to sewage treatment plant operation are not required as a matter of routine. They are made at the discretion of the plant supervisor or recommended by the service command engineer for plant control where necessary. Also, they are made for special studies of operation and design problems.



NOTE: MAKE CAN OF 14 GAGE COPPER STOCK. SOLDER ALL JOINTS, CRIMP ALL EDGES, SOLDER TUBING TO CAN AND BRACES

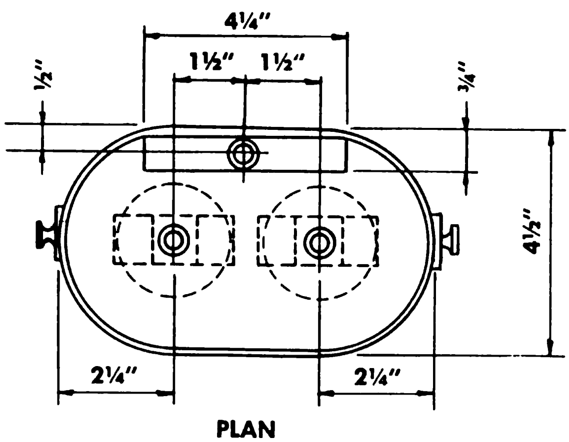


FIGURE 139. *Sampling device for dissolved-oxygen samples.*

SAMPLING AND ANALYSIS SCHEUDLE

Sampling point	Temperature	pH	Settleable solids	Suspended solids	Dissolved oxygen	BOD	Percent relative stability	Percent total solids	Percent volatile solids	Residual chlorine
Primary treatment:										
Plant influent	G	G	CG[1]	C		C				
Plant effluent (primary)		G	CG[1]	C		C				G[3]
Trickling filters:										
Filter effluent				C		C				
Activated sludge:										
Mixed liquor			G[1]	G[1]	G[1]					
Return sludge			G[1]	G[1]						
Plant effluent (final)	G		CG[1]	C	G	C	G[2]			G[3]
Sludge sampling:										
Raw sludge (daily)		G						C	C	
Digested sludge (as drawn)		G						C	C	
Digester sampling (monthly)	G	G						G	G	
Supernatant (weekly)		G						C		
Steam samples—weekly	G				G	G				

C—Composite samples.
G—Grab samples.
[1] Once per shift.
[2] Before chlorination.
[3] Hourly.

FIGURE 141. *Collection of composite sludge samples.*

FIGURE 140. *Collection of sludge sample from digester.*

159. Laboratory Procedures

a. HANDLING SAMPLES. Composite samples must be analyzed as soon as possible; they are kept as cold as possible before analysis. Extreme care must be used in separating portions of the composite for analysis to avoid segregating the solids. Constant stirring is necessary while portions are removed for testing. Composite-sludge samples are well mixed and a small quantity removed for the laboratory. Sludge-sample containers are kept clean to avoid including dried material in the laboratory portion.

b. TESTS. Laboratory test procedures in paragraphs 161 through 164 are included for use at plants performing only minimum tests. (See par. 158*d.*) Those in paragraphs 165 to 168 are not in current editions of the texts listed below. For all other tests, procedures in either of two texts are to be followed.

(1) *Standard Methods of Water and Sewage Analysis*, Eighth Edition, American Public Health Association, New York City.

(2) *Laboratory Manual for Chemical and Bacterial Analysis of Water and Sewage*, Third Edition

1943), Theroux, Eldridge, and Mallman, McGraw-Hill Company, New York City.

Note. These texts may be obtained by requisition to OCE. The first is the recognized standard but is suitable only for trained chemists. The second is written for plant operators and engineers with only limited knowledge of chemistry and has been used successfully in training shift operators in routine determinations; it contains procedures for preparing standard solutions, discussion of fundamental chemistry and analytical reactions, and directions for use and care of laboratory apparatus.

160. Expression of Test Results

Because of limitations of sampling accuracy and the nature of the tests, results are reported as follows:

a. Results between 0.1 and 1.0, two decimal places, as 0.74.

b. Results between 1 and 10, one decimal place, as 7.6.

c. Results between 10 and 100, the nearest whole number, as 34.

d. Results over 100, two significant figures, as 170, not 166.

161. Settleable Solids

a. Fill an Imhoff cone to the liter mark with the thoroughly mixed sewage sample.

b. Allow sewage to settle 45 minutes.

c. Stir gently with a rod, or rotate cone to cause solids adhering to upper sides to settle.

d. Settle 15 minutes more.

e. Read volume of solids settled in tip of cone and report as milliliters (ml) of 1-hour settleable solids per liter.

Note. If large voids occur in sludge in cone tip, sludge may be gently compacted with a rod before reading is made.

162. Relative Stability

Relative stability is the percent of oxygen available as dissolved, nitrite, and nitrate oxygen to the total oxygen required to satisfy the BOD. It is indicated by the number of days required to deplete available oxygen. Methylene blue dye turns colorless at this point. Sample must be taken before postchlorination because chlorine delays biological action.

a. Methylene blue indicator. Dissolve 0.5 gram of USP methylene blue in distilled water and dilute to 1 liter, or procure prepared indicator solution.

b. Procedure. (1) Completely fill a 4-ounce glass-stoppered bottle with sample, avoiding aeration.

(2) Add exactly 0.3 ml of methylene blue indicator solution below the liquid surface. If a larger bottle is used, increase amount of indicator proportionately.

(3) Insert stopper so air bubbles are not entrained beneath it.

(4) Keep bottle where the temperature is nearly constant and as near 20° C. as possible. In hot weather, a water bath may be satisfactory where a refrigerated incubator is not available.

(5) Observe bottle at least once each day for disappearance of color.

(6) Read and report percent relative stability from the following tabulation.

Days required for disappearance of color at 20° C.	*Relative stability (percent)*
0.5	11
1	21
2	37
3	50
4	60
5	68
6	75
7	80
8	84
9	87
10	90
11	92
12	94
13	95
14	96
16	97
18	98
20	99

Note. Above table conforms with the normal BOD rate. Thus, the 5-day BOD is 68 percent of the total BOD (exclusive of nitrification).

163. Hydrogen Ion Concentration (pH)

Hydrogen ion concentration (pH) is the degree of acidity or alkalinity exerted by a solution. Values below 7.0 indicate acid condition; values above 7.0, alkaline. Each whole number below or above this neutral point indicates a tenfold increase in the degree of acidity or alkalinity. Colormetric determination is made with commercial comparators having standard color disks or ampoules and indicator solutions to match. The following indicators are used in sewage treatment:

pH range	Indicator
6.0 to 7.6	Bromthymol blue
6.8 to 8.4	Phenol red

a. Procedure for sewage. (1) Fill sample tubes to mark with sample.

(2) Add indicator to one tube in amount specified by comparator manufacturer. This is usually 0.5 ml (10 drops) for a 10 ml tube and proportionately more for larger tubes. Mix and place in comparator.

(3) Place other sample tube (s) in comparator in line with color standards to compensate for sample turbidity and color.

(4) Match for color and read result immediately. If color matches standard at either the upper or lower end of indicator range, use another indicator. *Example:* If sample matches bromthymol blue color at pH 7.6, the actual pH may be 7.6 *or higher*. Therefore the phenol red indicator is used to check this value.

b. PROCEDURE FOR SLUDGE. (1) Place 10 ml of the sludge sample in a 100 ml graduate and dilute to the 100 ml mark with freshly boiled and cooled distilled water.

(2) Mix well and allow sludge to settle.

(3) Make pH test on upper liquid in accordance with procedure above for sewage.

164. Chlorine Residual

Residual chlorine is determined by the orthotolidine method with the same type of commercial comparator used for pH (par. 163), using orthotolidine standard color disks or ampoules and reagent.

a. PROCEDURE. (1) Fill tubes to mark with sample and place turbidity and color compensating tube (s) in comparator in line with standards.

(2) Add dropperful (10 to 15 drops) of orthotolidine reagent to other tube. Mix and let stand for 5 minutes. If blue color appears, add more reagent. If sample is colder than 50° F., warm by holding tube in hand.

(3) Place sample tube in comparator and hold towards light (preferably daylight).

(4) Match color and read residual. If color appears to be between two standards, report residual as average of the two. *Example:* Color appears halfway between 0.3 and 0.4 ppm. Report residual as 0.35 ppm.

b. INTERFERENCE. The orthotolidine method is subject to false color caused by nitrite compounds frequently contained in secondary effluents. The error is reduced by keeping the sample in the dark during the 5-minute color-development period. To determine and eliminate fully this error, use the othortolidine-arsenite (OTA) chlorine residual test. (See TM 5–660.)

165. Dissolved Oxygen, Sodium Azide Modification

The sodium azide modification of the Winkler dissolved-oxygen test contained in laboratory texts (par. 160*b*) is used for all secondary effluents to eliminate error caused by nitrites. It is simpler and quicker than the Rideal-Stewart modification prescribed by the texts.

a. REAGENTS. (1) *Alkaline potassium iodide.* (*a*) Dissolve 250 grams sodium hydroxide and 75 grams potassium iodide in distilled water to make 450 ml.

(*b*) Dissolve 5 grams sodium azide in 30 ml distilled water and add to the alkaline potassium iodide solution.

(*c*) Add enough distilled water to make 500 ml.

(2) *Other reagents.* Other reagents are identical with those for the Winkler method.

b. PROCEDURE. Proceed with test according to Winkler method, except 1.5 ml of concentrated sulfuric acid is added in the final step in place of 1.0 ml.

166. Inhibitory Reagent for Dissolved Oxygen Samples

The reagent below inhibits bacterial and enzymic reduction of dissolved oxygen between time of sample collection and test. It is used whenever this reduction is large in proportion to the amount of dissolved oxygen present, as in activated sludge, contact aeration liquor, raw sewage, preaeration-tank effluents, and highly polluted streams.

a. REAGENT. (1) Dissolve 50 grams copper sulfate in 500 ml distilled water.

(2) Dissolve 32 grams sulfamic acid in 475 ml distilled water by stirring. Do not heat.

(3) Mix the solutions and add 25 ml glacial acetic acid.

b. USE. Use 1 ml reagent for each 100 ml of sample. The following procedure is modified in accordance with sampling conditions.

(1) Add 10 ml reagent to a l-liter bottle fitted with tubes, as in figure 142.

(2) Immerse bottle in tank until filled.

(3) Allow solids to settle.

(4) Siphon upper liquid into an 8-ounce bottle for DO test. Avoid aeration of liquid during transfer.

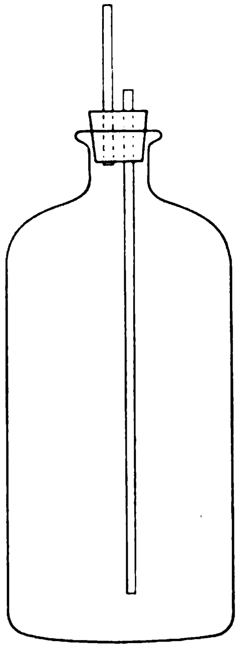


FIGURE 142. *Bottle and tubing for collection DO samples from mixed liquor.*

167. Immediate Oxygen Demand and Rate of Oxygen Utilization

The immediate oxygen demand test is used to indicate momentary degree of oxygen deficiency in sewage having little or no dissolved oxygen. It is used to determine effectiveness of preaeration (par. 57) and in contact aeration when no dissolved oxygen is present. The rate of oxygen utilization test is used in activated sludge plant operation. (See par. 114.)

a. IMMEDIATE OXYGEN DEMAND. (1) Prepare two 1-liter bottles with equipment as indicated in figure 142 and add 750 ml of BOD-diluting water to each.

(2) Add 10 ml of inhibitory reagent (par. 166) to first bottle.

(3) Immerse both bottles in the sewage to be sampled.

(4) Remove tubes and insert stoppers without entrainment of air. Tubes will be removed below sewage surface. Invert first bottle several times.

(5) Allow both samples to stand for 15 minutes.

(6) Add 10 ml of inhibitory reagent to second bottle and invert several times.

(7) After the solids have settled halfway, siphon into 8-ounce bottles, avoiding aeration.

(8) Make dissolved-oxygen test on each sample.

(9) Calculate and report as follows:

Immediate oxygen demand (ppm) = ppm DO in first bottle — ppm DO in second bottle.

b. RATE OF OXYGEN UTILIZATION. Proceed as in *a* above, except for the following modifications.

(1) In lieu of step 5 above, agitate contents of second bottle continually by inverting bottle for exactly 5 minutes. Then proceed to step 6.

(2) Determine oxygen demand as in step 9 and multiply by 12 to express it as rate of oxygen utilization per hour.

Note: The rate of activity of the sludge may require a longer or shorter period for step 1 in paragraph 167 *b* as determined by trail. Divide 60 by the number of minutes to obtain proper multiplier in next step for conversion to rate per hour.

168. Grease

The choice of solvents for grease analysis contained in present laboratory texts gives conflicting test results. The following procedure for grease analysis recently has been adopted as standard by the Federation of Sewage Works Associations, pending publication of the 9th Edition of *Standard Methods of Water and Sewage Analysis.* Grease is thereby defined as material extracted by this standard procedure.

a. REAGENTS AND SPECIAL APPARATUS. (1) Concentrated hydrochloric acid.

(2) Petroleum ether, boiling point 40° to 60° C.

(3) Absorbent cotton.

(4) Filter paper, number 1 Whatman, 9 centimeters.

(5) Separatory funnel, 1 liter.

(6) Soxhlet extraction apparatus.

b. PROCEDURE FOR SEWAGE. (1) Strongly acidify (pH 1.0) a 1-liter sample with concentrated hydrochloric acid.

(2) Boil for 2 minutes.

(3) Cool and chill in refrigerator (50° F. or lower) for at least 2 hours.

(4) Make absorbent cotton grease free by washing with petroleum ether and drying. Cut cotton to form disk to overlay 9-centimeter filter paper, and place in filtering funnel.

(5) Filter chilled sample through disk. Wipe sides and bottom of beaker carefully with a pad of grease-free cotton, taking care to collect all solid material. Insert cotton pad in filter.

(6) Place filter paper and cotton in an evaporating dish and dry in hot air oven at 103° C. for 30 to 40 minutes.

(7) Roll paper and pad, place in Soxhlet extraction thimble, and insert thimble in Soxhlet extractor. Assemble with weighted Soxhlet flask over water bath.

(8) Transfer filtrate (from step 5) to a separatory funnel, add 50 ml or more of petroleum ether and shake well. Draw off water layer and filter ether through the Soxhlet thimble into the weighted Soxhlet flask.

(9) Complete assembly of Soxhlet apparatus by attaching condenser. Extract at rate of 8 to 10 cycles per hour for 3 to 5 hours.

(10) Heat Soxhlet flask on water bath to drive off ether and dry in oven at 103° C. for 15 minutes. Draw off last traces of ether vapor by inserting a tube, connected to aspirator, into the warm flask.

(11) Cool in dessicator for 1 hour and weigh.

(12) Gain in weight in grams × 1,000 = ppm grease.

c. PROCEDURE FOR LIQUID SLUDGE. (1) Weigh a sample large enough to yield about 50 ml of grease.

(2) Proceed as in *b* above, omitting step 8.

(3) Determine percent dry solids on a separate sample.

(4) Gain in weight of flask in grams × 100 = percent grease.

Weight of dry solids in sample in grams

APPENDIX I
GLOSSARY

Acre-foot. Volume of water (stone in a trickling filter) required to cover 1 acre 1 foot deep. Equals 43,560 cubic feet.

Activated sludge. Sludge settled out of aerated sewage.

Activated-sludge process. Sewage treatment in which sewage is brought into contact with air and with biologically active sludge. The sludge is separated by sedimentation, leaving a clear effluent.

Adsorption. Adhesion in a thin layer of molecules of gases, dissolved substances, or liquids to the surfaces of solid bodies. Results in a relatively high concentration of gas or liquid on the surfaces.

Aeration. The process of adding air to a liquid, either by passing finely divided liquid through the air or by passing diffused air through a liquid.

Algae. Small plants, generally one-celled, which may give water a color, taste, odor, or turbidity when present in large numbers. They do not cause human disease.

Alternating device. Used in a sewage treatment plant to deliver sewage automatically or manually into different parallel treatment units according to a predetermined cycle.

Alum. Common name for aluminum sulfate, a chemical used for coagulation in purifying water and sewage.

Anaerobic. Able to live in absence of free oxygen.

Backfill. Refilling an excavation, usually after some object has been placed in it. Also, material placed in such an excavation.

Bacteria.

Pathogenic. Bacteria causing disease.

Saprophytic. Bacteria living on dead organic matter.

Baffles. Wood, metal, or masonry deflectors that divert, guide, or agitate the flow of liquid.

Bell-and-spigot-joint. A joint made by inserting the small end (spigot) of one pipe into the flared end (bell) of another. Calking is tamped around the spigot in the bell to seal the joint.

Biochemical action. Chemical action from the activity of living organisms.

Biochemical oxygen demand. Quantity of oxygen required for biochemical oxidation in a given time at a given temperature, usually for 5 days at 20° C.

Bleach. Chloride of lime, an unstable material of indefinite composition. Term sometimes applied incorrectly to calcium hypochlorite.

Blow-off. A waste gate or valve for discharging tank content or emptying a depressed sewer.

Branch. Special forms of vitrified sewer tile and cast-iron pipe for connecting to a sewer or water main.

Catch basin. Chamber or well designed to keep grit and debris out of a sewer.

Centigrade. Temperature scale with 0° as the freezing point and 100° as the boiling point of water.

Centrifuge. A device which separates a mixture of solids and liquids by rapid rotation.

Cesspool. Pit into which sewage or other liquid waste is discharged.

Leaching. Cesspool out of which the liquid seeps into surrounding soil.

Watertight. Cesspool with tight walls to prevent leaching and from which the contents must be removed at intervals.

Chamber. General term for a space inclosed by walls; a compartment. Often prefixed by a descriptive word, as *grit* or *screen* to indicate contents, or *discharge* or *flushing* to indicate purpose.

Diversion. Chamber containing a device for diverting all or part of the flow through it.

Flowing through. Upper story or compartment of a two-story sewage-sedimentation tank.

Screen. Chamber in a sewage treatment plant containing screens.

Settling. Sometimes used to designate the sedimentation compartment of a two-story tank, as in the case of the Imhoff tank.

Sludge digestion. Any chamber used for the digestion of sludge; lower story of an Imhoff tank.

Chlorination. Treatment with chlorine or chlorine compounds to disinfect or oxidize organic matter or retard its decomposition.

Chlorinator. Device for adding dissolved chlorine to sewage.

Chlorine liquid. Chlorine gas which has been liquefied under pressure.

Clarification. Process of removing suspended and colloidal matter from a turbid liquid.

Coagulation. Flocculation of colloidal material.

Coefficient. Number used in a formula to express the relationship of variables such as temperature and pressure under the conditions to which the formula applies.

Coefficient of discharge. Coefficient applied to formulas for discharge of water over or through weirs, orifices, or other hydraulic measuring devices to modify the theoretical formula to fit actual test results.

Colloid. Any substance finely dispersed so it will not settle from a liquid but not soluble in the liquid. It can be precipitated by chemical treatment or by contact with solid surfaces.

Contact aerator. Aeration tank holding asbestos plates, broken stone, coke, brushwood, or other media through which the sewage flows.

Contamination. Introduction of bacteria, sewage, or other substance into water, making it unfit for any given use.

Cradle. Support for pipe laid above the surface of the ground or in soft earth.

Cubic foot per second. The flow of 1 cubic foot of water past a given point in 1 second. Also termed second-foot.

Debris. Floating trash, suspended sediment, or bed load moved by a stream.

Detritus tank or chamber. Settling tank of short detention period, primarily for removing heavy settling solids. Detention chamber, larger than grit chamber, usually designed so sediment can be removed without interrupting sewage flow.

Diffuser. Porous plate or other device through which compressed air enters sewage.

Digestion. Biochemical decomposition of organic matter to form mineral and simpler organic compounds.

Dilution. Method of disposing of sewage or effluent by discharging into a stream or other body of water. Ratio of volume of flow of a stream to the volume of sewage or effluent discharged into it.

Discharge capacity. Maximum rate of flow of water passing through a conduit, channel, or other hydraulic structure.

Disinfection. Partial destruction, ordinarily by chemicals, of micro-organisms likely to cause disease.

Distributor. Used to apply sewage to the surface of a filter.

Fixed. Perforated pipes, notched troughs, sloping boards, or sprinkler nozzles.

Movable. Rotating or reciprocating perforated pipes or troughs that apply spray or a thin sheet of sewage.

Division box. Installed in a conduit to divide the flow equally or in various proportions to other channels.

Drying sludge. Process of drying sludge by drainage or evaporation through exposure to air, application of heat, or other methods.

Effluent. Partly or completely treated sewage flowing out of a sewage treatment device.

Stable. Effluent containing enough oxygen to satisfy its oxygen demand.

Examination of water or sewage.

Bacterial. Examination of water to determine contamination which might affect the sanitary quality of the water; an examination to determine the effectiveness of previous treatment.

Chemical. Determining the character and composition of material in solution of suspension.

Microscopic. Determining the presence of microscopic organic growth which might be objectionable or harmful.

Physical. Determining physical characteristics such as temperature, turbidity, settleable solids, color, taste and odor.

Facultative bacteria. Bacteria that can live in the presence or absence of free oxygen.

Filter.

Sand. Filter in which sand is the filtering medium.

Sprinkling. Trickling filter in which sewage is applied by spray.

Trickling. Filter having an artificial bed of coarse material over which sewage is distributed and through which it trickles to underdrains, permitting oxidation of organic matter by biochemical agencies.

Filtering media. Materials through which liquid applied to a filter must pass.

Filtration. Process of passing a liquid through a porous medium to remove suspended and colloidal matter and oxidize the dissolved organic matter. Sometimes loosely applied to removal of solids and liquid organic matter by treatment beds.

Final-settling tank. Tank through which effluent of a trickling filter or other oxidizing device passes for removal of settleable solids.

Fines. Finer-grained particles of soil, sand, or gravel.

Floc. Small gelatinous particles suspended in sewage. They are formed from colloidal solids, bacterial masses, and precipitated chemicals.

Flocculation. Formation of floc either by biochemical action or slow stirring and with or without addition of chemicals.

Flow. Movement of water, silt, sand, or other mobile material. Quantity of water carried by a streams or conduit, expressed in terms of volume per unit of time. Stream of water that is moving or flowing.

Dry-weather. Flow in a sewer during dry weather. Such flow consists entirely of sewage and wastes and does not include storm water. Flow of water in a stream during dry weather, usually entirely ground water.

Radial. Flow of liquid across a tank, either from the center to the periphery, or vice versa.

Flume. Open conduit of wood, masonry, or metal constructed on a uniform grade.

Flushing. Removing material deposited in a sewer or basin by washing out with a large flow of water or sewage.

Freeboard. Vertical distance from normal maximum level of liquid surface to the top of the channel or tank.

Fungi. Small nonchlorophyll plants which may cause disagreeable tastes and odors in water when they decompose.

Gauge.

Differential. Gauge that measures difference in pressure between two points in a pipe or receptacle containing a liquid.

Float. Device for measuring elevation of the surface of a liquid. Actuating element is a buoyant float.

Hook. Pointed U-shaped hook, attached to a staff or vernier scale, used to measure elevation of water surface accurately.

Indicator. Gauge that shows by a pointer the instantaneous value of such quantities as depth, pressure, velocity, stage, discharge, or movements and positions of water-controlling devices.

Pressure. Device for registering pressure of liquids or gases. It may be graduated in pounds per square inch or in equivalent feet of head.

Recording. Gauge that makes a continuous record, either graphical or in tabular form. Also called a *register.*

Staff. Graduated rod or board used to determine elevation of water surface in a stream channel, conduit, or tank.

Water level. Gauge indicating water level in a reservoir or other receptacle.

Gas vent. Passage for escape of gases of decomposition. Opening in digestion chamber of Imhoff tank to allow liberated gas to escape without passing through sewage in the settling chamber.

Grade. Elevation of the invert of a pipe line, canal, culvert, or sewer.

Hydraulic. Line joining the elevations to which water would rise in freely vented pipes from a closed conduit or water-bearing stratum under pressure. A line that coincides with the surface of the flowing water in an open channel flowing less than full and not under pressure.

Gravity system. System in which all sewage flows on descending grades from source; one requiring no pumping.

Grit chamber. A small detention chamber, or an enlargement of a sewer, designed to reduce sewage velocity enough to let the heaviest solid matter settle.

Head. Height of free surface of a body of water above a specified point.

Friction. Head or energy lost by water flowing in a stream or conduit because of disturbances set up by contact between moving water and its conduit and also because of intermolecular friction. Head losses from bends, expansions, obstructions, and impact are commonly included under this term.

Pressure. Head on any point in a conduit represented by the height of the hydraulic grade line above that point.

Static. Elevation of a motionless body of water above a specified point.

Total. Sum of static, friction, and velocity heads.

Velocity. Elevation required to impart a specified velocity to water. It is equal to the vertical distance a body must fall freely to acquire that velocity.

Weir. Vertical difference in elevation between the crest of a weir (apex of a triangular weir) and the water surface in the channel above the weir. It does not include the head corresponding to the velocity of approach unless so specified.

Hydraulics. Science concerned primarily with the mechanics of fluids, especially water.

Hydraulic gradient. Surface slope of liquid in a sewer.

Hydrogen ion concentration (*pH*). Index of the acidity or alkalinity of a liquid. The greater the hydrogen ion concentration, the greater the acidity of the liquid. A pH value of 7 is neutral; values below 7.0 are acid; values above 7.0 are alkaline. The pH value of a liquid is determined either by potentiometer measurements or by comparison with color standards after adding certain reagents.

Imhoff tank. Deep two-story tank having an upper, continuous-sedimentation chamber and a lower, sludge-digestion chamber. The floor of the upper slopes steeply to trapped slots through which solids settle into the lower. The lower chamber does not receive fresh sewage directly but has gas vents and means of taking out digested sludge from near the bottom.

Infection. Contamination of water with specific disease-producing organisms.

Infiltration. Leaching of water from ground into a sewer.

Influent. Sewage, raw or partially treated, flowing into any sewage treatment device.

Inlet. Surface connection to a closed drain; structure at the diversion end of a conduit; upstream end of any structure through which water may flow; connection between surface of ground and sewer for admitting surface or storm water.

Intermittent filter. Natural or artificial bed of sand or other fine-grained material to which sewage is applied in doses. Sewage flowing through is filtered, and the organic matter is oxidized.

Invert. Refers to floor, bottom, or lowest point in the internal cross section of a sewer.

Irrigation.

- *Broad.* Irrigation of crops with sewage. Differs from *sewage* farming because sewage disposal is the primary object of broad irrigation with the raising of crops incidental.
- *Subsurface.* Process of applying sewage to land by distributing it beneath the surface through open-jointed pipes or drains.
- *Surface.* Process of distributing sewage over surface of ground.

Leaching. Escape of water or sewage from a dry well or cesspool into surrounding permeable soil.

Manhole. Shaft into a sewer large enough to admit a man.

- *Drop.* Manhole having outside shaft in which sewage falls from the sewer to a lower level.
- *End.* Manhole at upstream end of a sewer.
- *Junction.* Manhole at junction of two or more sewers.
- *Line.* Manhole in sewer at place where no other sewers connect. It may be where the sewer changes direction either in line or grade.

Manhole cover.

- *Tight.* Cover without openings.
- *Ventilated.* Manhole cover with ventilation openings.

Manometer. U-shaped tube that contains a liquid. The surface of the liquid in one end of the tube moves up or down proportionally with increase or decrease in pressure on the liquid in the other end.

Micro-organism. Small living organisms which can be seen only under a microscope.

Nozzle. Short conical-shaped tube used as an outlet for a hose or pipe. Velocity of the emerging stream of water is increased because of the reduced cross-sectional area of the nozzle.

- *Sprinkler.* Nozzle used to apply sewage as spray to a trickling filter.

Overflow. Device that discharges excess storm flow from a combined sewer.

Oxygen deficiency. Difference between the amount of oxygen in water and total amount of oxygen needed to satisfy the biochemical demand. Usually expressed in parts per million.

Parshall flume. Special flume used to measure water flow in open conduits.

Percolation. Flow or trickling of a liquid through a relatively coarse filtering medium. Liquid usually does not fill the pores of the medium.

Pipe.

- *Suction.* Inlet of a pump through which water is lifted by suction from the water level to the pump.
- *Vitrified-clay.* Clay pipe having glazed surface that makes it watertight. Principally used for sewage.

Pneumatic ejector. Compressed-air device for lifting liquids or sludge. Liquid passes through an inlet check valve into a chamber. When the chamber is full, a float opens the compressed-air valve. Compressed air ejects the liquid through the outlet check valve into a discharge pipe.

Pollution. Introduction into clean water of any substances that contaminate it or make it objectionable in appearance and odor.

Potable. Term describing clean, relatively pure water considered satisfactory for domestic consumption.

Precipitation. Term applied to rainfall or snowfall; the passing of a substance out of solution into solid form.

Chemical. Precipitation of a substance in solution, caused by adding chemicals. Accelerating sedimentation of sewage solids by adding chemicals that coagulate the suspended or colloidal matter. Process of softening hard water by adding lime or sodium carbonate.

Priming. Starting the flow in a pump or siphon.

Protozoa. One-celled animals, the lowest and simplest form of animal life. Some types found in water are similar to algae, which are plants.

Pump.

Air-chamber. Displacement pump with an air chamber in which air is alternately compressed and expanded by water which the pump displaces, resulting in a more even rate of discharge.

Centrifugal. Impeller pump having straight or curved vanes fixed radially on a shaft and inclosed in a casing. Water enters near the center of the vanes. Rotating velocity imparted to water is converted to pressure.

Impeller. Any pump that moves water by application of power from a mechanical agency or medium.

Reciprocating. Displacement pump with one or more closed cylinders. Each cylinder contains a piston or plunger that draws liquid into the cylinder through the inlet valve and forces it out through the outlet valve. When only one end of the cylinder acts on the liquid, the pump is *single acting;* when both ends act on the liquid, it is *double acting.*

Purification. Removal, by natural or artificial methods, of objectionable matter from water or sewage.

Degree of. Measure of how completely such impurities as bacteria and organic matter are destroyed or removed from sewage.

Self. Destruction of objectionable impurities from water or sewage by natural means.

Putrefaction. Decomposition of organic matter with ill-smelling products. Occurs under conditions of oxygen deficiency.

Putrescibility. Susceptibility of waste waters, sewage, effluent, or sludge to putrefaction. The relative tendency of organic matter to decompose in the absence of oxygen.

Rainfall. Amount of rain, usually expressed as depth in inches on a unit area, that reaches the surface of the earth.

Relative stability. Ratio, expressed in percentage, of oxygen *available* to oxygen *required* for complete biochemical oxidation of organic matters in waste water, sewage, effluent, or diluted sewage.

Riparian right. Common-law right of the owner of land abutting upon a natural body of water to use such water "undiminished in quantity and unaffected in quality". This right has been abrogated in a number of western States and greatly modified in others. In general, each riparian owner may make reasonable use of water, extent of use being governed by reasonable requirements of other riparian owners and by quantity of water available.

Sanitary survey. A study of the environmental conditions of a water source that might affect its use for domestic consumption.

Saturation. Condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

Saturation deficit. Difference, expressed in percentage, between the amount of dissolved oxygen in a stream and the amount needed to produce oxygen saturation under given conditions.

Screen. Device used to retain coarse sewage solids. The screening element may consist of grating, wire mesh, perforated plate, or parallel bars, rods, or wires. Screen openings may have any shape, usually circular or rectangular slots.

Bar. Screen having parallel bars or rods placed over an opening to prevent entrance of large solids.

Coarse. Screen whose openings are usually larger than 1 inch least dimension.

Fine. Relative term usually applied to screens with openings whose least dimensions are ¼ inch or less.

Screening. Process of removing, by racks or screens, the relatively coarse and suspended solids in water, sewage, or other liquids.

Screenings. Material removed from sewage by screens and racks.

Scum. Sewage solids floating at the surface buoyed up by entrained gas, grease, or other substance.

Second-foot (cfs). Term used to express rate of flow of water. Equals 1 cubic foot per second.

Sediment. Any material carried in suspension by water which settles to bottom when water loses motion.

Sedimentation. Settling of suspended matter in a liquid by gravity.

Sedimentation tank. Tank or basin in which sewage is retained until suspended matter settles.

Separate system. System of sewers in which sewage and storm water are carried in separate conduits.

Septic tank. Settling tank that retains the sludge in immediate contact with the sewage that flows through the tank. Sludge is retained long enough to secure satisfactory decomposition of organic solids by anaerobic bacterial action.

Settleable solids. Suspended solids which settle in quiescent sewage within a reasonable period.

Settling. See *sedimentation.*

Settling chamber. Sometimes used to designate the sedimentation compartment of a two-story tank, as in the case of the Imhoff tank. (See *sedimentation tank.*)

Sewage. Wash water and water-carried animal, culinary, and industrial wastes. Liquid waste containing human excreta and other matter flowing in or from a house drainage system or sewer, excreta including feces, urine, secretions from the skin, and expectoration. Liquid wastes from institutions, stables, and business buildings. Combination of liquid wastes with such ground, surface, and storm water as may enter the sewers.

- *Dilute.* Sewage containing a relatively small quantity of organic matter.
- *Domestic.* Sewage derived principally from dwellings, business buildings, institutions, and like sources. It may or may not contain ground water, surface water or storm water, and may contain a small proportion of industrial wastes. Somewhat more general term than sanitary sewage.
- *Filtered.* Effluent of a sewage filter.
- *Fresh.* Sewage of recent origin which still contains dissolved oxygen.
- *Sanitary.* Sewage from the sanitary conveniences of a dwelling, business building, factory, or institution. The water supply of a community after it has been used and discharged into a sewer.
- *Septic.* Sewage undergoing putrefaction in the absence of oxygen.
- *Settled.* Sewage from which some of the solids have settled out in a tank.
- *Stale.* Sewage containing little or no oxygen but free from putrefaction.
- *Storm.* Liquid flowing in combined or storm sewers as a result of rainfall.
- *Strong.* Sewage containing organic matter in excess of the normal quantity.
- *Treated.* Sewage that has received more or less complete treatment.

Sewage disposal. Riddance of sewage by any method.

Sewage treatment. Any artificial process for removing or altering the objectionable constituents of sewage and rendering it less offensive or dangerous.

Sewage treatment works. Treatment plant and means of disposal of sewage.

Sewer. Pipe or conduit, generally closed but not normally flowing full, for carrying sewage and other waste liquids.

- *Branch.* Sewer receiving sewage from a relatively small area.
- *Building.* Pipe conveying sewage from a single building to a common sewer or point of immediate disposal.
- *Combined.* Used to carry domestic or sanitary sewage, industrial waste, and storm sewage.
- *Depressed.* Sewer that usually crosses beneath a valley or water course. It runs full at greater than atmospheric pressure because its profile is below the hydraulic grade line. Commonly called *inverted siphon.*
- *Intercepting.* Sewer cutting transversely a number of other sewers to intercept the flow.
- *Lateral.* Sewer that discharges into a branch or other sewer and has no other common sewer tributary to it.
- *Main.* Sewer receiving the discharge of many tributary branches. Also called *trunk sewer.*
- *Outfall.* Sewer that receives sewage from the treatment plant or collection system and conducts it to the point of final discharge or disposition.
- *Relief.* Sewer installed to relieve an existing sewer of inadequate capacity.
- *Sanitary.* Sewer that carries sanitary sewage and excludes as far as possible the storm sewage, surface water, and ground water. Usually used to carry industrial wastes from the area served.
- *Storm-overflow.* Sewer used to carry excess of storm flow from a main or intercepting sewer to an independent outlet.

Sewerage system. Collecting system of sewers and appurtenances.

Sewerage works. Term applied to facilities for collecting, treating, and disposing of sewage.

Silt. Fine particles of earth, sand, or soil carried in suspension by flowing water. The term sometimes includes material rolled along the bed of the stream.

Siphon. INVERTED U-shaped tube, one end longer than the other, used to transfer liquids from a higher to a lower level over an intermediate elevation.

Inverted. See *depressed sewer.*

Sleek. Thin oily film on the surface of water.

Sludge. A semiliquid mass formed by mixing water with solids. Sewage suspended solids that have settled out in tanks or basins.

Conditioning. Chemical treatment of liquid sludge before dewatering.

Humus. Sludge deposited in final or secondary-settling tanks after sewage has passed through a trickling filter or other oxidizing device. Sludge that resembles humus in appearance.

Liquid. Sludge containing enough water, usually more than 80 percent, to permit it to flow by gravity.

Spadable. Sludge dry enough, usually under 70 percent moisture, to be shoveled from the drying bed.

Sludge bed. Natural or artificial layers of porous material upon which sludge is dried by drainage or evaporation.

Sludge cake. Mass resulting from sludge pressing or vacuum filtering.

Sludge concentration. Process of reducing water content of sludge, leaving it still a liquid.

Sludge dewatering. General term for removing part of the water in sludge, with or without heat, by draining, pressing, centrifuging, exhausting, passing between rollers, or acid flotation. The process involves reducing sludge from liquid to spadable sludge.

Sludge drying. Process of drying sludge by drainage, evaporation, exposure to air, or application of heat.

Specific gravity. Ratio of the weight of a unit volume of any substance to an equal volume of water under standard conditions.

Spiral-flow tank. Tank used in the activated sludge process. Sewage is given a spiral motion in its flow through the tank by introducing air through a line of diffusers located at one side near the bottom.

Stability. Ability of sewage, effluent, or digested sludge to resist putrefaction.

Sterilization. Destruction of all micro-organisms by heat or chemical action.

Stilling well. Pipe, chamber, or compartment with closed sides and bottom, used to check pulsations or surges while permitting the water level to rise and fall with the major fluctuations of the main body of water.

Storm water. That portion of the rainfall which runs off the surface during and immediately after a storm.

Stream. Body of water flowing in a natural surface channel. Body of water flowing in an open or closed conduit. Jet of water issuing from an opening such as a nozzle or a fissure in rock.

Discharge. Rate of flow of water, usually expressed cubic feet per second.

Gauging. Measuring velocity of a stream of water.

Suspended matter. Solids physically suspended in sewage.

Tank. Any artificial receptacle through which liquids pass or in which they are held.

Dortmund. Vertical-flow sedimentation tank with a hopper bottom. Sewage enters near the bottom, rises and overflows at the surface, and the sludge is removed from the bottom.

Dosing. Tank used to accumulate raw or partially treated sewage for discharge to contact beds or filters. The discharge is regulated for correct distribution essential to subsequent treatment.

Horizontal-flow. Tank or basin, with or without baffles, in which the direction of flow is generally horizontal.

Imhoff. See *Imhoff tank.*

Settling. See *sedimentation tank.*

Skimming. Chamber arranged so floating matter rises and remains on the surface until removed. The liquid flows out continuously under partitions, curtain walls, or scum boards.

Multiple dosing. Two or more dosing tanks of equal capacity. Each is equipped with a dosing device, interconnected to fill and discharge tanks alternately or in rotation. Two tanks so arranged are called *twin dosing tanks.*

Trap. Device used to prevent liquid from reversing its direction of flow in a conduit or from passing a given point. Device preventing sewer air or gases from backing up and escaping through a plumbing fixture.

Grease. Device by which grease in sewage is held at the surface of a basin so it can be skimmed off.

Tributary. Stream or other body of water, surface or underground, that contributes its water to another and larger stream or body of water.

Turbidity. Condition of water when it contains visible material in suspension. Such material does not have to be large enough to be seen as individual particles by the naked eye, but the cloudiness in the water must be caused by material in suspension, not in solution.

Turbulence. State of flow of water in which the water is agitated by cross currents and eddies. Opposed to quiet or quiescent flow.

Vacuum. Condition existing when the pressure in closed space is much lower than the surrounding atmospheric pressure. Strictly speaking, the term applies to a condition within an inclosed space from which all air, gas, vapor, or other substance has been exhausted. In general use, the term is applied to any space where negative pressure exists.

Valve. Device installed in a pipe line for controlling the magnitude and direction of flow.

Air. A valve that either releases air from a pipe line automatically without loss of water or introduces air into a line automatically if the internal pressure becomes less than atmospheric pressure.

Automatic. Valve that opens or closes when predetermined conditions are reached.

Check. Valve that prevents reversal in direction of flow.

Flap. Valve that opens and shuts by rotating around hinge on one edge.

Foot. Valve in the bottom of the pump suction pipe. It opens to let water enter the suction pipe, but closes to prevent water from passing out at the bottom.

Gate. Valve with flat disk that slides over the opening through which water passes and fits tightly against it.

Needle. Valve with circular outlet through which flow is controlled by a tapered needle extending through the outlet. Needle reduces outlet area as it is advanced and enlarges area as it is withdrawn.

Pump. Opening through which water enters and leaves cylinders of a displacement pump.

Rotary. Valve having approximately a cylindrical-shaped casing with an opening of same diameter as the pipe line. When the interior gate, which turns through a 90° angle, is opened fully, liquid flows through valve without constriction or appreciable resistance.

Safety. Valve that automatically opens when predetermined conditions, usually of pressure, are exceeded in a pipe line or other closed receptacle containing liquids or gases. It prevents damage that might occur if conditions exceeded safe limitations.

Velocity.

Approach. Average velocity of water flowing in a channel of approach to a weir or tank inlet.

Mean. Average velocity of a stream flowing in a channel or conduit at a given cross section. It equals the discharge divided by the cross-sectional area of the section.

Venturi meter. Device for measuring flow of liquid through closed conduits or pipes. It consists of a Venturi tube and a flow-registering device.

Water-borne disease. Disease caused by organisms carried in water. The most common water-borne diseases are typhoid fever, Asiatic cholera, dysentery, and other intestinal diseases. Also, anthrax germs and some parasitic worms can be carried by water.

Weir.

Contracted. A weir with its crest extending only part way across the channel. The crest is terminated by partitions in the same plane as the crest which rise above the water level on the upstream side of the weir and produce a contraction in the width of the stream of water as it leaves the notch.

Free. Weir that is not submerged. Either the tail water is below the weir crest or the flow is not affected by tail water.

Measuring. Device to measure rate of flow of water. It generally consists of a rectangular, trapezoidal, triangular, or other notch in a thin vertical plate. The water flows through the notch, and its depth of overflow (head) is an index of the rate of flow.

Parabolic. Measuring weir with a notch shaped as a vertical parabola designed so the discharge of the weir is directly proportional to the head.

Rectangular. Measuring weir with a rectangular notch.

Submerged. Weir placed in a stream so the downstream water level is equal to or higher than the weir crest.

Suppressed. Weir with one or both sides or bottom flush with the channel of approach. This prevents contraction of the nappe (sheet of water above the weir crest) adjacent to the flush side or bottom. Suppression may be on one end, both ends, bottom, or any combination.

Triangular. Measuring weir with a triangular notch. Usually used to measure small flows. Also called *V-notch* weir.

APPENDIX II
ABBREVIATIONS

BOD	biochemical oxygen demand (5-day period at 20° C. unless otherwise stated)
C	Centigrade
cu	cubic
cfm	cubic feet per minute
cfs	cubic feet per second
DO	dissolved oxygen
F	Fahrenheit
ft	feet
gal	gallon
gpd	gallons per day
gcd	gallons per capita per day
gpm	gallons per minute
gpd/sq ft	gallons per day per square foot
hp	horsepower
hp-hr	horsepower-hour
hr	hour
in	inch
kw	kilowatt
kw-hr	kilowatt hour
l	liter
lb	pound
max	maximum
mg	milligram
min	minute, also minimum
ml	milliliter
mg	million gallons
mgd	million gallons per day
mgad	million gallons per acre per day
ppm	parts per million.
psi	pounds per square inch
rpm	revolutions per minute
RS	relative stability
sec	second
sq	square
SS	suspended solids
sq ft	square foot
vol	volume
wt	weight

APPENDIX III
TABLES

TABLE I.

G. C. H.

FREE-FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUME

FPS X .646317 = M G D
M G D X 1.54723 = FPS

FPS X 448.831 = G P M
G P M X .002228 = FPS

THROAT WIDTH

HEAD		6"			9"			12"			18"			24"		
FT	IN	FPS	G P M	M G D	FPS	G P M	M G D	FPS	G P M	M G D	FPS	G P M	M G D	FPS	G P M	M G D
0.10	1 3/16	0.05	22.4	0.032	0.09	40.4	.0580									
0.11	1 5/16	0.06	26.9	0.039	0.10	44.9	.0650									
0.12	1 7/16	0.07	31.4	0.045	0.12	53.8	.0775									
0.13	1 9/16	0.08	35.9	0.052	0.14	62.8	.0905									
0.14	1 11/16	0.09	40.4	0.058	0.15	67.3	.0970									
0.15	1 13/16	0.10	44.9	0.065	0.17	76.3	.1100									
0.16	1 15/16	0.11	49.4	0.071	0.19	85.2	.1230									
0.17	2 1/16	0.12	53.8	0.077	0.20	89.8	.1290									
0.18	2 3/16	0.14	62.8	0.090	0.22	98.7	.1420									
0.19	2 1/4	0.15	67.3	0.097	0.24	107.7	.1550									
0.20	2 3/8	0.16	71.6	0.103	0.26	116.9	.1680	0.35	157.1	0.226	0.51	229.0	0.330	0.66	296.3	0.426
0.21	2 1/2	0.18	80.7	0.116	0.28	125.7	.1810	0.37	166.1	0.239	0.55	247.0	0.355	0.71	318.7	0.458
0.22	2 5/8	0.19	85.2	0.123	0.30	134.6	.1940	0.40	179.5	0.259	0.59	265.0	0.381	0.77	345.6	0.498
0.23	2 3/4	0.20	89.8	0.129	0.32	143.6	.2070	0.43	193.0	0.278	0.63	283.0	0.407	0.82	368.0	0.530
0.24	2 7/8	0.22	98.7	0.142	0.35	157.1	.2260	0.46	206.5	0.297	0.67	301.0	0.433	0.88	395.0	0.569
0.25	3	0.23	103.3	0.149	0.37	166.1	.2390	0.49	219.9	0.316	0.71	318.7	0.458	0.93	417.5	0.601
0.26	3 1/8	0.25	112.2	0.162	0.39	175.1	.2520	0.51	229.0	0.330	0.76	341.1	0.491	0.99	444.3	0.640
0.27	3 1/4	0.26	116.9	0.168	0.41	184.0	.2650	0.54	242.3	0.349	0.80	359.0	0.517	1.05	471.3	0.679
0.28	3 3/8	0.28	125.7	0.181	0.44	197.5	.2840	0.58	260.3	0.374	0.85	381.5	0.549	1.11	498.2	0.717
0.29	3 1/2	0.29	130.2	0.187	0.46	206.5	.2970	0.61	274.0	0.394	0.90	404.0	0.582	1.18	530.0	0.763
0.30	3 5/8	0.31	139.2	0.203	0.49	219.9	.3160	0.64	287.3	0.414	0.94	422.0	0.607	1.24	556.6	0.801
0.31	3 3/4	0.32	143.6	0.207	0.51	229.0	.3300	0.68	305.2	0.439	0.99	444.3	0.640	1.30	583.4	0.840
0.32	3 13/16	0.34	152.6	0.220	0.54	242.3	.3490	0.71	318.7	0.458	1.04	466.8	0.672	1.37	615.0	0.886
0.33	3 15/16	0.36	161.5	0.233	0.56	251.3	.3620	0.74	332.0	0.478	1.09	489.0	0.704	1.44	646.0	0.930
0.34	4 1/16	0.38	170.5	0.246	0.59	265.0	.3810	0.77	345.6	0.498	1.14	512.0	0.737	1.50	673.2	0.969
0.35	4 3/16	0.39	175.1	0.252	0.62	278.0	.4010	0.80	359.0	0.517	1.19	534.0	0.769	1.57	705.0	1.015
0.36	4 5/16	0.41	184.0	0.265	0.64	287.3	.4140	0.84	377.0	0.543	1.25	561.0	0.808	1.64	736.0	1.060
0.37	4 7/16	0.43	193.0	0.278	0.67	301.0	.4330	0.88	395.0	0.569	1.30	583.4	0.840	1.72	772.0	1.111
0.38	4 9/16	0.45	201.9	0.291	0.70	314.0	.4520	0.92	412.9	0.594	1.36	610.0	0.879	1.79	803.4	1.156
0.39	4 11/16	0.47	210.9	0.304	0.73	327.6	.4720	0.95	426.0	0.614	1.41	633.0	0.911	1.86	835.0	1.202
0.40	4 13/16	0.48	215.5	0.310	0.76	341.1	.4912	0.99	444.3	0.640	1.47	659.0	0.950	1.93	866.0	1.247
0.41	4 15/16	0.50	224.4	0.323	0.78	350.0	.5040	1.03	462.0	0.666	1.53	686.0	0.989	2.01	902.0	1.299
0.42	5 1/16	0.52	233.3	0.336	0.81	363.5	.5240	1.07	480.0	0.692	1.58	709.0	1.021	2.09	938.0	1.350
0.43	5 3/16	0.54	242.3	0.349	0.84	377.0	.5430	1.11	498.1	0.717	1.64	736.0	1.060	2.16	969.0	1.396
0.44	5 1/4	0.56	251.3	0.362	0.87	390.4	.5620	1.15	516.0	0.743	1.70	763.0	1.098	2.24	1005	1.447
0.45	5 3/8	0.58	260.3	0.375	0.90	404.0	.5820	1.19	534.0	0.769	1.76	790.0	1.137	2.32	1041	1.499
0.46	5 1/2	0.61	274.0	0.394	0.94	422.0	.6075	1.23	552.0	0.795	1.82	816.0	1.176	2.40	1077	1.551
0.47	5 5/8	0.63	283.0	0.407	0.97	435.0	.6270	1.27	570.0	0.821	1.88	843.0	1.215	2.48	1113	1.602
0.48	5 3/4	0.65	292.0	0.420	1.00	448.8	.6460	1.31	588.0	0.847	1.94	870.0	1.254	2.57	1153	1.661
0.49	5 7/8	0.67	301.0	0.433	1.03	462.0	.6660	1.35	606.0	0.872	2.00	898.0	1.293	2.65	1189	1.712
0.50	6	0.69	310.0	0.446	1.06	475.7	.6850	1.39	624.0	0.898	2.06	925.0	1.331	2.73	1225	1.764
0.51	6 1/8	0.71	318.7	0.459	1.10	493.7	.7109	1.44	646.0	0.930	2.13	956.0	1.376	2.82	1266	1.822
0.52	6 1/4	0.73	327.6	0.472	1.13	507.0	.7300	1.48	664.0	0.956	2.19	983.0	1.415	2.90	1301	1.875
0.53	6 3/8	0.76	341.1	0.491	1.16	521.0	.7500	1.52	682.0	0.982	2.25	1010	1.454	2.99	1342	1.932
0.54	6 1/2	0.78	350.0	0.504	1.20	538.0	.7760	1.57	705.0	1.015	2.32	1041	1.499	3.08	1382	1.990
0.55	6 5/8	0.80	359.0	0.517	1.23	552.0	.7950	1.62	727.0	1.047	2.39	1073	1.545	3.17	1422	2.049
0.56	6 3/4	0.82	368.0	0.530	1.26	565.5	.8140	1.66	745.0	1.073	2.45	1099	1.583	3.26	1463	2.107
0.57	6 13/16	0.85	381.5	0.549	1.30	583.4	.8400	1.70	763.0	1.098	2.52	1131	1.628	3.35	1504	2.165
0.58	6 15/16	0.87	390.4	0.562	1.33	597.0	.8600	1.75	786.0	1.131	2.59	1163	1.674	3.44	1544	2.224
0.59	7 1/16	0.89	399.5	0.575	1.37	615.0	.8860	1.80	808.0	1.163	2.66	1194	1.719	3.53	1585	2.282
0.60	7 3/16	0.92	412.9	0.595	1.40	628.0	.9050	1.84	826.0	1.189	2.73	1225	1.764	3.62	1625	2.340
0.61	7 5/16	0.94	422.0	0.608	1.44	646.0	.9300	1.88	843.0	1.215	2.80	1257	1.809	3.72	1670	2.404
0.62	7 7/16	0.97	435.0	0.627	1.48	664.0	.9560	1.93	866.0	1.247	2.87	1290	1.855	3.81	1710	2.463
0.63	7 9/16	0.99	444.3	0.640	1.51	678.0	.9760	1.98	889.0	1.280	2.95	1324	1.907	3.91	1755	2.527
0.64	7 11/16	1.02	457.8	0.659	1.55	696.0	1.002	2.03	911.0	1.312	3.02	1355	1.952	4.01	1800	2.592
0.65	7 13/16	1.04	466.8	0.672	1.59	714.0	1.028	2.08	934.0	1.345	3.09	1387	1.997	4.11	1845	2.656
0.66	7 15/16	1.07	480.0	0.692	1.63	732.0	1.054	2.13	956.0	1.376	3.17	1422	2.049	4.20	1885	2.714
0.67	8 1/16	1.10	493.7	0.711	1.66	745.0	1.073	2.18	978.0	1.409	3.24	1454	2.094	4.30	1930	2.780
0.68	8 3/16	1.12	503.0	0.724	1.70	763.0	1.098	2.23	1001	1.441	3.31	1486	2.140	4.40	1975	2.844
0.69	8 1/4	1.15	516.0	0.743	1.74	781.0	1.125	2.28	1024	1.474	3.39	1522	2.191	4.50	2020	2.908
0.70	8 3/8	1.17	525.1	0.756	1.78	799.0	1.151	2.33	1046	1.506	3.46	1553	2.236	4.60	2065	2.973

Cont'd

N. W. N.

DISCHARGE TABLE, CONTINUED

THROAT WIDTH

HEAD		6"			9"			12"			18"			24"		
FT	IN	FPS	GPM	MGD	FPS	GPM	MGD	FPS	GPM	MGD	FPS	GPM	MGD	FPS	GPM	MGD
0.71	8½	1.20	538	0.776	1.82	816	1.176	2.38	1068	1.538	3.54	1590	2.288	4.70	2111	3.038
0.72	8⅝	1.23	552	0.795	1.86	835	1.202	2.43	1091	1.571	3.62	1625	2.340	4.81	2159	3.110
0.73	8¾	1.26	566	0.814	1.90	853	1.228	2.48	1113	1.602	3.69	1656	2.385	4.91	2204	3.174
0.74	8⅞	1.28	575	0.827	1.94	870	1.254	2.53	1136	1.635	3.77	1692	2.437	5.02	2253	3.245
0.75	9	1.31	588	0.847	1.98	889	1.280	2.58	1158	1.667	3.85	1728	2.488	5.12	2300	3.310
0.76	9⅛	1.34	601	0.866	2.02	907	1.306	2.63	1182	1.700	3.93	1764	2.540	5.23	2347	3.380
0.77	9¼	1.36	610	0.879	2.06	925	1.331	2.68	1203	1.732	4.01	1800	2.592	5.34	2397	3.451
0.78	9⅜	1.39	624	0.898	2.10	943	1.357	2.74	1230	1.771	4.09	1836	2.643	5.44	2442	3.516
0.79	9½	1.42	637	0.918	2.14	960	1.383	2.80	1257	1.809	4.17	1872	2.695	5.55	2491	3.587
0.80	9⅝	1.45	651	0.937	2.18	978	1.409	2.85	1280	1.842	4.26	1912	2.753	5.66	2540	3.658
0.81	9¾	1.48	664	0.957	2.22	996	1.435	2.90	1301	1.875	4.34	1948	2.805	5.77	2597	3.730
0.82	9 13/16	1.50	673	0.970	2.27	1019	1.467	2.96	1329	1.913	4.42	1984	2.857	5.88	2639	3.800
0.83	9 15/16	1.53	686	0.989	2.31	1036	1.493	3.02	1355	1.952	4.50	2020	2.908	6.00	2692	3.878
0.84	10 1/16	1.56	700	1.008	2.35	1054	1.518	3.07	1377	1.984	4.59	2060	2.967	6.11	2742	3.950
0.85	10 3/16	1.59	714	1.028	2.39	1073	1.545	3.12	1400	2.017	4.67	2096	3.018	6.22	2791	4.020
0.86	10 5/16	1.62	727	1.047	2.44	1095	1.577	3.18	1427	2.055	4.76	2136	3.076	6.33	2841	4.091
0.87	10 7/16	1.65	741	1.066	2.48	1113	1.602	3.24	1454	2.094	4.84	2171	3.128	6.44	2891	4.162
0.88	10 9/16	1.68	754	1.085	2.52	1131	1.628	3.29	1476	2.126	4.93	2212	3.186	6.56	2944	4.240
0.89	10 11/16	1.71	768	1.105	2.57	1153	1.661	3.35	1504	2.165	5.01	2248	3.238	6.68	2998	4.318
0.90	10 13/16	1.74	781	1.125	2.61	1171	1.686	3.41	1530	2.203	5.10	2289	3.296	6.80	3052	4.394
0.91	10 15/16	1.77	794	1.144	2.66	1194	1.720	3.46	1553	2.236	5.19	2329	3.354	6.92	3105	4.473
0.92	11 1/16	1.81	812	1.169	2.70	1212	1.745	3.52	1580	2.275	5.28	2370	3.413	7.03	3155	4.543
0.93	11 3/16	1.84	826	1.189	2.75	1234	1.777	3.58	1606	2.313	5.37	2410	3.470	7.15	3209	4.621
0.94	11¼	1.87	839	1.208	2.79	1252	1.803	3.64	1633	2.352	5.46	2450	3.529	7.27	3263	4.698
0.95	11⅜	1.90	853	1.228	2.84	1274	1.835	3.70	1661	2391	5.55	2491	3.587	7.39	3316	4.777
0.96	11½	1.93	866	1.247	2.88	1292	1.862	3.76	1687	2.430	5.64	2531	3.645	7.51	3370	4.853
0.97	11⅝	1.97	884	1.273	2.93	1315	1.894	3.82	1714	2.469	5.73	2572	3.703	7.63	3425	4.930
0.98	11¾	2.00	898	1.293	2.98	1337	1.926	3.88	1741	2.510	5.82	2612	3.762	7.75	3478	5.009
0.99	11⅞	2.03	911	1.312	3.02	1355	1.952	3.94	1768	2.547	5.91	2653	3.820	7.88	3537	5.093
1.00	12	2.06	925	1.331	3.07	1377	1.984	4.00	1795	2.585	6.00	2692	3.878	8.00	3590	5.170
1.01	12⅛	2.09	938	1.350	3.12	1400	2.017	4.06	1822	2.624	6.09	2733	3.936	8.12	3645	5.248
1.02	12¼	2.12	952	1.370	3.17	1422	2.049	4.12	1849	2.662	6.19	2778	4.000	8.25	3703	5.332
1.03	12⅜	2.16	969	1.396	3.21	1440	2.074	4.18	1876	2.701	6.28	2818	4.059	8.38	3761	5.416
1.04	12½	2.19	983	1.415	3.26	1463	2.107	4.25	1908	2.747	6.37	2859	4.117	8.50	3815	5.494
1.05	12⅝	2.22	996	1.435	3.31	1486	2.140	4.31	1934	2.786	6.47	2904	4.182	8.63	3873	5.578
1.06	12¾	2.26	1014	1.460	3.36	1508	2.172	4.37	1961	2.824	6.56	2944	4.240	8.76	3932	5.662
1.07	12 13/16	2.29	1027	1.480	3.40	1526	2.197	4.43	1988	2.863	6.66	2989	4.304	8.88	3986	5.740
1.08	12 15/16	2.32	1041	1.500	3.45	1548	2.230	4.50	2020	2.908	6.75	3030	4.362	9.01	4044	5.823
1.09	13 1/16	2.36	1060	1.525	3.50	1571	2.262	4.56	2047	2.947	6.85	3075	4.427	9.14	4102	5.907
1.10	13 3/16	2.40	1077	1.551	3.55	1594	2.295	4.62	2074	2.986	6.95	3119	4.492	9.27	4161	5.991
1.11	13 5/16	2.43	1091	1.571	3.60	1616	2.327	4.68	2101	3.025	7.04	3160	4.550	9.40	4220	6.075
1.12	13 7/16	2.46	1104	1.590	3.65	1638	2.360	4.75	2132	3.070	7.14	3205	4.614	9.54	4282	6.165
1.13	13 9/16	2.50	1122	1.616	3.70	1661	2.391	4.82	2164	3.115	7.24	3250	4.680	9.67	4340	6.250
1.14	13 11/16	2.53	1136	1.635	3.75	1683	2.424	4.88	2190	3.154	7.34	3294	4.744	9.80	4399	6.334
1.15	13 13/16	2.57	1153	1.661	3.80	1706	2.458	4.94	2217	3.193	7.44	3339	4.810	9.94	4461	6.424
1.16	13 15/16	2.60	1167	1.681	3.85	1728	2.490	5.01	2248	3.238	7.54	3384	4.873	10.1	4578	6.528
1.17	14 1/16	2.64	1185	1.706	3.90	1750	2.521	5.08	2280	3.283	7.64	3429	4.940	10.2	4581	6.593
1.18	14 3/16	2.68	1203	1.732	3.95	1773	2.553	5.15	2311	3.329	7.74	3474	5.003	10.3	4623	6.657
1.19	14¼	2.71	1217	1.752	4.01	1800	2.592	5.21	2338	3.367	7.84	3519	5.067	10.5	4713	6.786
1.20	14⅜	2.75	1234	1.777	4.06	1822	2.624	5.28	2370	3.413	7.94	3564	5.132	10.6	4760	6.851
1.21	14½	2.78	1248	1.797	4.11	1845	2.656	5.34	2397	3.451	8.05	3613	5.203	10.8	4850	6.980
1.22	14⅝	2.82	1266	1.823	4.16	1867	2.689	5.41	2428	3.497	8.15	3658	5.267	10.9	4892	7.045
1.23	14¾	2.86	1284	1.848	4.22	1894	2.728	5.48	2460	3.542	8.25	3703	5.337	11.0	4940	7.110
1.24	14⅞	2.89	1297	1.867	4.27	1917	2.760	5.55	2491	3.587	8.36	3752	5.403	11.2	5027	7.240
1.25	15	2.93	1315	1.894	4.32	1939	2.793	5.62	2522	3.632	8.46	3800	5.468	11.3	5072	7.304
1.26	15⅛	2.97	1333	1.920	4.37	1961	2.824	5.69	2554	3.678	8.56	3842	5.533	11.5	5162	7.433
1.27	15¼	3.01	1350	1.945	4.43	1988	2.863	5.76	2585	3.723	8.67	3892	5.603	11.6	5210	7.497
1.28	15⅜	3.04	1364	1.965	4.48	2011	2.896	5.82	2612	3.762	8.77	3936	5.668	11.7	5251	7.562
1.29	15½	3.08	1382	1.991	4.53	2033	2.928	5.89	2644	3.807	8.88	3986	5.740	11.9	5341	7.691
1.30	15⅝	3.12	1400	2.017	4.59	2060	2.967	5.96	2675	3.852	8.99	4035	5.810	12.0	5386	7.756
1.31	15¾	3.16	1418	2.042	4.64	2083	3.000	6.03	2710	3.900	9.09	4080	5.875	12.2	5476	7.885

Table II. Conversion factors.

1 milligram per liter	= 1 part per million
1 kilogram	= 2.205 pounds
1 pound	= 453.6 grams
1 cubic foot	= 7.48 gallons
1 cubic foot of water	= 62.4 pounds
1 gallon of water	= 8.34 pounds.
1 gallon	= 3.785 liters
1 liter	= 0.2642 gallon
1 liter	= 1.057 quarts
1 cubic foot per second	= 646, 300 gallons per 24 hours
1 cubic foot per second	= 449 gallons per minute
1,000,000 gallons per 24 hours	= 1.547 cubic feet per second
1,000,000 gallons per 24 hours	= 694 gallons per minute
1 part per million	= 8.34 pounds per million gallons
1 acre	= 43,560 square feet
1 acre-foot	= 1613 cubic yards
1 pound per square inch	= 2.307 feet of water
1 pound per square inch	= 2.036 inches of mercury
1 inch of mercury	= 13.4 inches of water
1 kilowatt	= 0.746 horse power
1 kilowatt hour	= 0.746 horse power hours
1 ounce	= 28.3495 grams

Centigrade temperature = (Fahrenheit — 32) × 5/9
Fahrenheit temperature = (Centigrade × 9/5) + 32

Table III. Solubility of oxygen in fresh water.

Temperature °C.	°F.	Dissolved oxygen ppm
0	32.0	14.62
1	33.8	14.23
2	35.6	13.84
3	37.4	13.48
4	39.2	13.13
5	41.0	12.80
6	42.8	12.48
7	44.6	12.17
8	46.4	11.87
9	48.2	11.59
10	50.0	11.33
11	51.8	11.08
12	53.6	10.83
13	55.4	10.60
14	57.2	10.37
15	59.0	10.15
16	60.8	9.95
17	62.6	9.74
18	64.4	9.54
19	66.2	9.35
20	68.0	9.17

(Continued)

Table III.—Continued. Solubility of oxygen in fresh water.

Temperature °C.	°F.	Dissolved oxygen, ppm
21	69.8	8.99
22	71.6	8.83
23	73.4	8.68
24	75.2	8.53
25	77.0	8.38
26	78.8	8.22
27	80.6	8.07
28	82.4	7.92
29	84.2	7.77
30	86.0	7.63
31	87.8	7.50
32	89.6	7.38
33	91.4	7.26
34	93.2	7.14
35	95.0	7.03

Table IV. Discharge table for 90° V-notch weir.

Head in.	Head ft.	Discharge gpm
1¼	.10	4
1½	.12	6
1⅝	.14	9
1⅞	.16	12
2⅛	.18	16
2⅜	.20	21
2⅝	.22	27
2⅞	.24	33
3⅛	.26	40
3⅜	.28	49
3⅝	.30	58
3⅞	.32	69
4⅛	.34	79
4⅜	.36	91
4½	.38	104
4¾	.40	118
5	.42	133
5¼	.44	149
5½	.46	166
5¾	.48	184
6	.50	204
6⅝	.55	258
7¼	.60	320
7¾	.65	390
8⅜	.70	470
9	.75	555
9⅝	.80	653
10¼	.85	758
10¾	.90	872
11⅜	.95	997
12	1.00	1130

TABLE V. *Discharge in gallons per minute for retangular weirs with complete end contraction.*

Head		Length of weir					
Inches	Feet	1 ft	2 ft	3 ft	4 ft	5 ft	Addition for 1 ft increase in length
1	0.083	35.4	71.5	107.5	143.5	179.8	36.04
1 1/16	0.088	38.8	78.3	118.	159.5	197.	39.5
1 1/8	0.094	42.67	85.	128.2	171.22	214.5	43.02
1 3/16	0.099	45.9	92.2	139.	185.85	232.5	46.85
1 1/4	0.104	49.5	99.8	150.4	200.85	250.4	50.45
1 5/16	0.109	53.	107.	161.5	215.5	270.	54.
1 3/8	0.115	56.75	114.7	173.	231.	289.5	58.
1 7/16	0.120	60.7	123.	185.	247.1	309.5	62.1
1 1/2	0.125	64.9	131.	197.	262.15	329.5	65.15
1 9/16	0.130	68.5	139.	209.	279.1	350.	70.1
1 5/8	0.135	72.5	147.	222.	297.	371.5	74.7
1 11/16	0.140	77.	156.	235.	314.15	392.6	79.15
1 3/4	0.146	81.	164.	248.	331.2	415.	83.2
1 13/16	0.151	85.4	173.	262.	349.75	436.5	87.75
1 7/8	0.156	89.5	182.	275.	367.7	460.	92.7
1 15/16	0.161	94.	191.	289.	386.2	480.9	97.2
2	0.167	98.9	200.5	302.	404.	506.	102.
2 1/16	0.172	103.	210.	316.	422.8	530.	106.8
2 1/8	0.177	107.8	219.9	332.	443.7	555.	111.7
2 3/16	0.182	112.4	229.	345.	461.6	579.	116.6
2 1/4	0.187	117.	239.	361.	482.3	605.	121.3
2 5/16	0.193	122.5	249.	376.	503.	629.	127.
2 3/8	0.198	127.	259.	390.5	523.	655.	132.
2 7/16	0.203	132.	269.	406.	543.	680.	137.2
2 1/2	0.208	137.	279.	422.	564.9	706.	142.9
2 9/16	0.213	142.	289.	438.	586.	732.	148.
2 5/8	0.219	147.1	300.	453.	607.	760.	153.5
2 11/16	0.224	151.4	310.5	470.	629.	785.	159.
2 3/4	0.229	157.	321.5	485.	649.2	815.	164.2
2 13/16	0.234	162.	332.	501.5	672.	832.5	170.15
2 7/8	0.240	168.	343.	520.	695.3	870.	175.3
2 15/16	0.245	173.	354.	535.	716.4	898.	181.4
3	0.250	178.	366.	552.	739.3	926.	187.3
3 1/16	0.255	183.	377.	569.	763.	956.	193.5
3 1/8	0.260	189.1	388.	588.	787.2	986.	199.2
3 3/16	0.266	194.	400.	605.	811.	1015.	205.5
3 1/4	0.271	199.	410.5	624.	835.	1047.	211.
3 5/16	0.276	205.6	422.	640.	858.	1076.	217.6
3 3/8	0.281	210.8	435.	659.	883.	1105.	224.
3 7/16	0.286	216.5	446.	676.	906.	1138.	229.8
3 1/2	0.292	222.8	458.	695.	931.15	1167.	236.15
3 9/16	0.297	228.	470.	714.	956.2	1200.	242.2
3 5/8	0.302	234.	483.	731.	980.4	1230.	249.4
3 11/16	0.307	240.	495.	750.	1005.9	1260.	255.9
3 3/4	0.312	245.	506.	769.	1031.2	1292.	262.2
3 13/16	0.318	251.	520.	789.	1058.	1328.	268.6
3 7/8	0.323	256.5	533.	808.	1089.	1355.	274.5
3 15/16	0.328	263.	545.	825.	1107.	1390.	282.
4	0.333	269.	556.	846.	1134.	1424.	288.
4 1/16	0.338	275.6	570.	866.	1162.	1454.	296.
4 1/8	0.344	281.6	584.	885.	1186.9	1490.	301.9
4 3/16	0.349	287.6	596.	907.5	1215.	1518.	309.
4 1/4	0.354	293.6	610.	925.	1241.	1553.	316.
4 5/16	0.359	300.	623.	945.	1268.	1590.	323.
4 3/8	0.365	306.	636.	966.	1297.	1628.	330.5
4 7/16	0.370	312.	650.	986.	1323.	1660.	336.8
4 1/2	0.375	318.	663.	1006.	1350.	1696.	344.
4 9/16	0.380	325.	676.	1030.	1382.	1730.	351.5
4 5/8	0.385	331.	690.	1050.	1408.	1768.	358.
4 11/16	0.390	336.6	704.	1069.	1435.	1801.	366.
4 3/4	0.396	344.	717.5	1091.	1465.	1835.	374.
4 13/16	0.401	350.	731.	1111.	1492.	1875.	380.9
4 7/8	0.406	356.6	744.5	1131.	1519.	1908.	388.2
4 15/16	0.411	363.7	759.	1156.	1551.9	1948.	395.9
5	0.417	370.	772.	1175.	1579.3	1985.	404.3
5 1/16	0.422	376.5	785.	1200.	1611.5	2018.	410.5
5 1/8	0.427	382.5	800.	1220.	1639.	2056.	419.4
5 3/16	0.432	388.	815.	1239.	1665.	2094.	426.
5 1/4	0.437	395.5	830.	1262.	1696.4	2130.	434.4
5 5/16	0.443	401.	844.	1285.	1726.	2168.	441.
5 3/8	0.448	409.	857.	1310.	1760.	2208.	450.
5 7/16	0.453	415.	871.	1330.	1787.5	2243.	457.5

Head		Length of weir					
Inches	Feet	1 ft	2 ft	3 ft	4 ft	5 ft	Addition for 1 ft increase in length
5 1/2	0.458	421.6	887.	1352.	1817.5	2282.	465.5
5 9/16	0.463	428.5	903.	1376.	1846.9	2321.	470.9
5 5/8	0.469	435.5	915.	1395.	1875.	2358.	480.
5 11/16	0.474	442.5	932.5	1419.	1907.	2400.	487.6
5 3/4	0.479	449.	947.5	1442.	1937.	2440.	495.
5 13/16	0.484	456.2	960.	1465.	1968.5	2480.	503.5
5 7/8	0.490	462.6	977.	1490.	2001.	2515.	511.
5 15/16	0.495	470.	993.	1515.	2034.	2559.	519.6
6	0.500	476.5	1005.	1535.	2063.	2600.	528.
6 1/16	0.505		1021.	1561.	2097.	2640.	536.
6 1/8	0.510		1039.	1582.	2125.	2675.	543.
6 3/16	0.515		1051.	1609.	2163.	2716.	554.
6 1/4	0.521		1068.	1632.	2192.	2760.	560.
6 5/16	0.526		1083.	1655.	2225.	2801.	570.
6 3/8	0.531		1100.	1679.	2254.	2844.	575.
6 7/16	0.536		1112.	1704.	2290.	2881.	586.
6 1/2	0.542		1130.	1742.	2338.	2920.	596.
6 9/16	0.547		1147.	1760.	2362.	2962.	602.3
6 5/8	0.552		1161.	1779.	2392.8	3005.	613.8
6 11/16	0.557		1178.	1803.	2422.	3047.	617.8
6 3/4	0.563		1193.	1826.	2455.9	3094.	629.9
6 13/16	0.568		1210.	1853.	2493.	3139.	640.
6 7/8	0.573		1226.	1878.	2523.5	3180.	645.5
6 15/16	0.578		1240.	1903.	2559.	3219.	656.
7	0.583		1258.	1928.	2596.	3260.	668.
7 1/16	0.589		1272.	1949.	2621.5	3300.	672.5
7 1/8	0.594		1290.	1976.	2658.	3342.	682.5
7 3/16	0.599		1309.	2000.	2695.	3384.	695.
7 1/4	0.604		1322.	2029.	2730.5	3436.	701.5
7 5/16	0.609		1339.	2058.	2768.	3480.	710.
7 3/8	0.615		1356.	2080.	2799.6	3522.	719.6
7 7/16	0.620		1371.	2105.	2834.	3570.	729.
7 1/2	0.625		1390.	2130.	2866.	3609.	736.
7 9/16	0.630		1408.	2155.	2901.	3658.	746.
7 5/8	0.635		1423.	2179.	2934.	3700.	755.
7 11/16	0.641		1439.	2212.	2976.	3745.	764.
7 3/4	0.646		1458.	2238.	3012.	3785.	774.
7 13/16	0.651		1471.	2260.	3042.	3820.	782.
7 7/8	0.656		1490.	2286.	3078.	3860.	792.
7 15/16	0.661		1506.	2310.	3113.	3903.	803.
8	0.667		1525.	2338.	3151.5	3956.	813.5
8 1/16	0.672		1541.	2365.	3186.5	4000.	821.5
8 1/8	0.677		1556.	2396.	3227.	4045.	831.
8 3/16	0.682		1572.	2419.	3259.	4090.	840.
8 1/4	0.688		1592.	2442.	3292.	4140.	850.
8 5/16	0.693		1601.	2460.	3320.	4178.	860.
8 3/8	0.698		1619.	2493.	3364.	4227.	871.
8 7/16	0.703		1636.	2516.	3395.6	4272.	879.6
8 1/2	0.708		1652.	2540.	3430.	4312.	889.7
8 9/16	0.714		1670.	2570.	3469.	4362.	899.
8 5/8	0.719		1689.	2595.	3504.	4415.	909.
8 11/16	0.724		1706.	2626.	3545.	4460.	919.
8 3/4	0.729		1723.	2656.	3585.	4511.	929.
8 13/16	0.734		1741.	2680.	3620.	4552.	940.
8 7/8	0.740		1760.	2705.	3654.	4600.	949.
8 15/16	0.745		1777.	2739.	3698.	4648.	959.
9	0.750		1791.	2765.	3734.5	4699.	969.5
9 1/16	0.755		1810.	2792.	3771.	4749.	979.
9 1/8	0.760		1830.	2816.	3811.	4799.	995.
9 3/16	0.765		1848.	2844.	3843.	4849.	999.
9 1/4	0.771		1866.	2876.	3887.	4899.	1011.
9 5/16	0.776		1880.	2901.	3921.	4949.	1020.
9 3/8	0.781		1898.	2927.	3958.	4999.	1031.
9 7/16	0.786		1918.	2960.	4001.	5049.	1041.
9 1/2	0.792		1939.	2985.	4036.	5098.	1051.
9 9/16	0.797		1955.	3017.	4077.	5145.	1060.
9 5/8	0.802		1970.	3041.	4113.	5185.	1072.
9 11/16	0.807		1987.	3073.	4155.	5227.	1082.
9 3/4	0.812		2006.	3101.	4192.	5288.	1091.
9 13/16	0.818		2025.	3131.	4234.	5340.	1103.
9 7/8	0.823		2045.	3160.	4273.	5393.	1112.
9 15/16	0.828		2065.	3190.	4315.	5443.	1125.
10	0.833		2085.	3216.	4352.	5490.	1136.

APPENDIX IV
REFERENCES

1. Books for Operators of Small Sewage Treatment Plants

Laboratory Manual for Chemical and Bacterial Analysis of Water and Sewage, Theroux, Eldridge, and Mallman.

Operation and Control of Sewage Treatment Plants, N. Y. State Department of Health.

Principles of Sewage Treatment, Rudolfs.

Sewage Treatment, Imhoff and Fair.

Sewage Treatment Works, Keefer.

Standard Methods of Water and Sewage Analysis, American Public Health Association.

ABC of Hydrogen Ion Control, LaMotte Co.

Modern pH Control, W. A. Taylor Co.

Sewerage and Sewage Treatment, Hardenbergh.

Sewage Plant Operation, W. H. Wisely.

2. Additional Books for Operators of Larger Treatment Plants

American Sewage Practice, Vol. 3, Metcalf and Eddy.

Handbook of Hydraulics, King.

Industrial Waste Treatment Practice, Eldridge.

Sewerage, 11th Ed., Folwell.

Sewerage & Sewage Treatment, Babbitt.

Stream Sanitation, Phelps.

Solving Sewage Problems, Fuller & McClintock.

Water Supply and Sewerage, Steel.

3. Magazines and Bulletins

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TM 5–634, Garbage and Refuse Disposal.

TM 5–660, Water Supply and Treatment.

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